Short Communication

STABILITY OF INDIVIDUAL DIFFERENCE OF COLD-INDUCED VASODILATATION RESPONSE AT DIFFERENT ROOM AND WATER TEMPERATURES AND IMMERSION TIME

異なる室温、水温および浸漬時間での
局所耐寒反応の個人差の一様性

Frostbite is one of the typical injuries caused by occupational or accidental exposure to the extreme cold. The response of cold-induced vasodilatation (CIVD) which Lewis¹⁾ first described as "hunting reaction" has been found to be related to the severity of cold injury; those with higher response are less susceptible to frostbite and vice-versa.^{2,3)} Yoshimura and Iida³⁾ developed a local cold tolerance test on the basis of this CIVD observed in human fingers and thereafter Nakamura *et al.*⁴⁾ modified part of the evaluation way in this test. The present tests have been, however, performed at a water temperature of 0°C with immersion time of 30 min. Finger immersion under this test condition is very painful. We, therefore, attempted to examine the response at temperatures above 0°C and the immersion time within 30 min in order to obtain an optimal temperature and immersion time at which CIVD could be observed with minimum discomfort and to gain satisfactory information on the indices of CIVD.

Subjects and methods. Two kinds of experiments were conducted in the afternoon on 10 healthy male and female subjects with an average age of 21.3 years, in a climate chamber maintained at two different room temperatures of 30°C (to be called high environmental temperature experiment "HE") and 22°C (to be called low environmental temperature experiment "LE").

In each experiment, the subjects sat in a chair and their left middle finger was immersed up to its base for 30 min in a cold water bath. Three series of observations were made at 0°C, 5°C, and 10°C water temperatures, successively with 40 min intervals. The water was constantly stirred by a motor-driven pump. Skin temperature of the immersed finger was measured continuously by using a copper-constantan thermocouple attached to the back of the middle phalanx of the finger. Immediately after each cold exposure, discomfort of cold pain was reported by a 5 point scale (1: none,

Fig. 1. Typical CIVD response and four indices of it at 0°C, 5°C and 10°C water temperatures.

2: a little painful, 3: painful, 4: very painful, 5: extremely painful). For comparison of the degree and the individual difference of CIVD, the following indices of the reaction were selected as shown in Fig. 1.

TFR=temperature of the first rise after immersion, TTR=time of the first temperature rise after immersion, AT=amplitude of temperature reaction, $MST_i (5 \leq i \leq 30 \text{ min})$ =mean skin temperature 5 min to i min following the immersion; MST_{30} is equal to MST used in the conventional test.^{3,4)}

Results and discussion. Figure 2 gives the average with standard deviation in each indices of CIVD for all subjects at different room and water temperatures. Under HE condition where marked CIVD was noted, TFR, AT and MST_{30} were greater and TTR was shorter at every water temperature; while under LE condition, poor CIVD was observed and in some cases no response was seen at 10°C water temperature. The degree of

Table 1. Correlation coefficients of the order of individual difference in each index of CIVD between different room temperatures (LE×HE).

	TFR	TTR	MST_{30}	AT
0°C	0.518	0.398	0.518	0.504
5°C	0.754*	0.515	0.671*	0.658*
10°C	0.028	-0.065	0.136	0.330

* $P < 0.05$, ** $P < 0.01$

Table 2. Correlation coefficients of the order of individual difference in each index of CIVD between different water temperatures (0°C×5°C, 0°C×10°C).

	TFR	TTR	MST_{30}	AT
LE (22°C)				
$R_{0^\circ\text{C} \times 5^\circ\text{C}}$	0.627*	0.897*	0.923*	0.777*
$R_{0^\circ\text{C} \times 10^\circ\text{C}}$	-0.217	0.366	0.109	-0.038
HE (30°C)				
$R_{0^\circ\text{C} \times 5^\circ\text{C}}$	0.404	0.740*	0.604*	0.661*
$R_{0^\circ\text{C} \times 10^\circ\text{C}}$	0.260	-0.007	0.629*	0.605*

* $P < 0.05$, ** $P < 0.01$

Fig. 2. Average and standard deviation in each index of CIVD for all subjects at different room (22°C, 30°C) and water (0°C, 5°C, 10°C) temperatures; $\square$ = LE (22°C), $\blacksquare$ = HE (30°C)

pain complained by each subjects apparently reduced with the rise in water temperature under both HE and LE conditions.

Correlation coefficients in the indices of CIVD between HE and LE, which might explain regularity in the order of the individual difference, were shown in Table 1. Relatively high correlation coefficients at 0°C, especially significant ones at 5°C water temperature were obtained for each indices in CIVD, though low correlation coefficients were found at 10°C water temperature. Judging from the high correlation between 0°C and 5°C of water temperatures presented in Table 2, it might be concluded that the individual difference in most indices of CIVD was almost put in the same order under both HE and LE conditions, even though the water temperature rises from 0°C to 5°C. On the other hand, significant correlation in the order of its individual difference between 0°C and 10°C water temperature was found only for MST_{30} and AT under HE condition, though there was no correlation in it under LE condition. These low correlations in the order of its individual difference under some conditions mentioned above appear due to the reduction in the absolute individual variations in CIVD indices by extreme depression of CIVD at 10°C water temperature under LE condition. The above mentioned depression of CIVD would be the result of small heat content in low environmental temperature.⁵⁾

In the next place, the stability of the order of the individual difference was also investigated between MST_{30} defined above and MST_i ($5 \leq i \leq 29$) calculated by shortening the immersion time every 1 min from the conventional immersion time (30 min). The result of calculation of the correlation coefficients between MST_{30} and MST_i ($5 \leq i \leq 29$) was shown by water temperature in Fig. 3. At any of three different water temperatures, even more than

Fig. 3. Correlation coefficients in the order of the individual difference between MST_{30} and MST_i ($5 \leq i \leq 29$) by water temperature

half curtailment of immersion time maintained the stability of the individual difference. The degree of the correlation was found maximal at 5°C water temperature.

It can thus be concluded that under such room and water temperature conditions as CIVD markedly appears, the order of individual difference in CIVD was almost the same despite the change in water and room temperatures and the shortening more than half of the immersion time. Considering the decrease of discomfort of the subjects as the water temperature rises, it seems practicable that under such experimental condition as marked CIVD occurs, the local cold tolerance test should be performed above 0°C and within 10 to 20 min from the viewpoint of industrial health practice.

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Received for publication, November 10, 1982

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