

EFFECT OF FOUR WEEKS REPETITIVE MILD COLD WATER IMMERSION ON THERMOREGULATORY RESPONSES DURING IMMERSION AND CIVD RESPONSE

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INTRODUCTION

Previous studies have reported about the changes in thermoregulatory responses due to cold adaptation, and several types of cold adaptation (insulative, metabolic and hypothermic adaptation) have been described (Bittel, 1987; Tipton et al., 2008). The differences in cold exposure and physical characteristics have been considered as the factors affecting different types of adaptation. However it has remained uncertain that the relationship between the cold adaptation type and factors affecting adaptation.

Besides the whole body cold adaptation, there have been studies about peripheral cold adaptation as a cold induced vasodilatation (CIVD) in finger immersed in cold water. It was generally found that the cold adapted subjects had a more pronounced CIVD responses (Daanen, 2003; Geurts et al., 2006). It is considered that further investigation was needed to clarify the relationship between the changes in CIVD responses and whole body thermoregulatory responses after a cold acclimation. There is a possibility that the CIVD response might be one of the cold acclimation parameters affecting the thermoregulatory responses related to cold acclimation types.

This study investigated the effects of 4 weeks repetitive mild cold water immersion on the thermoregulatory responses during immersion and CIVD responses during finger cold water immersion. Additionally, another purpose was to clarify the factors affecting the different cold acclimation types.

METHODS

Experimental procedure

Seven healthy male subjects (age: 21.3 ± 0.8 years, height: 171.8 ± 6.6 cm, weight: 61.4 ± 8.0 kg, %fat: $12.8 \pm 3.6\%$, surface area: 1.72 ± 0.13 m²) took part in this study and offered written informed consent. Surface area (SA) was estimated from height and weight (DuBois and DuBois, 1916).

Subjects with ordinary swimming trunks were immersed to chest level repeatedly in 26°C water for 60 min, three days/week, for four weeks. At the first (pre) and last (post) exposure of this cold acclimation period, subjects underwent an immersion test measuring their thermoregulatory responses. Additionally, they underwent a finger cold immersion test measuring their cold induced vasodilatation (CIVD) at pre and post acclimation period.

Immersion test

After the 10 min rest in air (27°C, 50%RH) measuring baseline data for each measurement, subjects were immersed to their chest level in 26°C water for 60 min. They did not immerse their head, upper trunk and upper extremities. During the experiment, rectal temperature (T_{re}) and eight local skin temperatures were measured using thermistor sensors (LT-ST08; Nikkiso-Therm Co. Ltd., Japan). The thermistor probe for T_{re} was inserted 13cm from the anal sphincter. These temperature data were recorded by a data logger (LT-8A; Gram Corporation, Japan) every two sec. These data were averaged over one min. The mean skin temperature (\bar{T}_{sk}) was estimated from a modified Hardy and DuBois' equation (1938).

Expired gases were continuously assessed using an automatic respiromonitor (AE-300S; Minato Medical Science Co. Ltd., Japan) every five sec. Values of the oxygen uptake (\dot{V}_{O_2}) and respiratory exchange ratio (RER) were averaged every five min. Metabolic heat production (M) was calculated from \dot{V}_{O_2} and RER .

Skin blood flow on the forearm (LDF) was measured by laser Doppler flowmetry (FLO-C1 OMEGAWAVE, INC., Japan) during experiments. The LDF was then divided by mean blood pressure (MBP) to yield the cutaneous vascular conductance (CVC). Data of LDF and CVC were indicated as the percentage of the baseline value.

CIVD test

After the ten min rest in air (27°C, 50%RH), subjects immersed their right middle finger up to the second joint into 5°C water for 30 min. A skin temperature sensor was attached to the palmar side of the distal phalanx. Finger skin temperature (T_{fing}) was recorded every two sec. The following parameters derived from T_{fing} were analyzed according to the previous definition (Daanen, 2003).

The minimum temperature (T_{min}) is defined as the lowest T_{fing} just before CIVD starts. The onset time (t_{onset}) is the time from finger immersion until T_{min} . The maximum temperature (T_{max}) is the highest T_{fing} during CIVD. The peak time (t_{peak}) is the time from finger immersion until T_{max} . The time interval between t_{onset} and t_{peak} is defined as Δt_{peak} . The amplitude is the difference between T_{min} and T_{max} . The mean T_{fing} averaged from t_{onset} to the end of immersion is defined as CIVD_{index} (Takano et al., 1989).

Statistical analyses

Comparisons of datasets were performed using a repeated two-way (acclimation x time) analysis of variance and further tested using a paired t -test at various time points between experimental conditions. Statistical significance was set at $p < 0.05$.

RESULTS

Thermoregulatory responses during immersion

T_{re} decreased on average around 1.0°C over 60 min immersions in pre and post acclimation, and no difference was observed between the two conditions. A significant main effect of acclimation was observed in \bar{T}_{sk} , and significantly lower in the post condition compared to pre acclimation ($p < 0.05$).

A significant main effect of acclimation was observed in %LDF, and significantly lower in the post condition compared to pre acclimation ($p < 0.05$, Figure 1). A similar main effect was

observed in %CVC, and significantly lower in the post acclimation condition compared to pre acclimation ($p < 0.05$).

No significant difference was observed in metabolic heat production (M/SA) between pre and post acclimation.

A composite diagram of pre-post acclimation difference in mean M/SA and in mean %LDF averaged during 60 min immersion are shown in Figure 2. All subjects showed lower mean %LDF in the post condition compared to pre acclimation, which indicated the insulative cold acclimation. Some subjects also showed higher mean M/SA in the post condition compared to pre acclimation, indicating the metabolic cold acclimation.

A significant negative correlation was observed between pre-post difference in mean M/SA and averaged T_{re} at 60 min immersion during cold acclimation period ($r = -0.77$, $p < 0.05$); subjects indicating lower T_{re} at 60 min showed larger increase in M/SA . And a correlation tendency was observed between pre-post difference in mean M/SA and subject's $SA/weight$ ($r = 0.71$, $p = 0.08$); subjects with larger $SA/weight$ showed larger increase in M/SA .

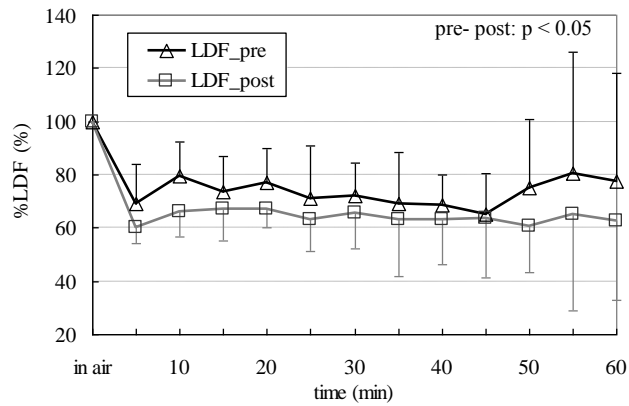


Fig. 1 Change in %LDF_{forearm} (mean \pm SD)

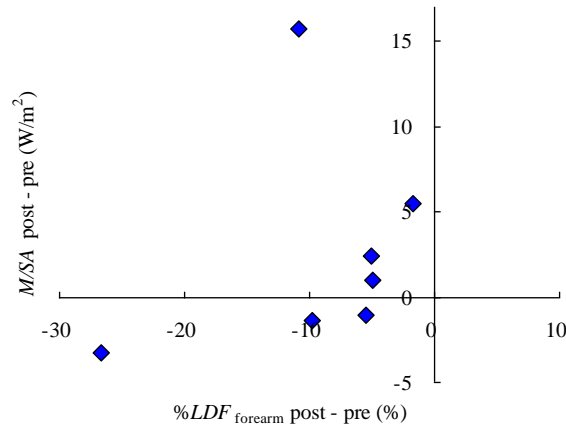


Fig. 2 Composite diagram of pre-post acclimation difference in mean M/SA and in mean %LDF

CIVD responses

CIVD parameters are presented in Table 1. T_{max} , amplitude and CIVD_{index} were significantly lower in post condition compared to pre acclimation ($p < 0.01$). These results indicated a blunted CIVD response and an enhanced vasoconstriction after cold acclimation.

Table 1 CIVD parameters at pre and post cold immersion training

		pre		post		t-test
		mean	SD	mean	SD	p
T_{min}	(°C)	7.6	1.4	6.5	1.0	0.14
t_{onset}	(sec)	208.3	44.8	254.3	31.3	0.05
T_{max}	(°C)	14.7	2.5	11.0	2.3	<0.01
t_{peak}	(sec)	528.9	129.7	509.4	94.7	0.74
Amplitude	(°C)	7.1	2.0	4.6	1.7	<0.01
Δt_{peak}	(sec)	320.6	101.1	255.1	69.9	0.17
CIVD _{index}	(°C)	12.3	0.8	9.1	1.1	<0.01

CONCLUSIONS

This study investigated the effects of four weeks repetitive mild cold water immersion on the thermoregulatory responses during immersion and CIVD responses. Subjects showed lower \bar{T}_{sk} and %LDF in post acclimation compared to pre acclimation, while no difference was observed in M/SA . From these results, it was considered that most of the subjects showed insulative type cold acclimation. While a significant negative correlation was observed between pre-post differences in mean M/SA and averaged T_{re} at 60 min immersion during cold acclimation period. The decrease of T_{re} during cold acclimation period might be related to the metabolic cold acclimation. Blunted CIVD responses were observed after cold acclimation.

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