COOLING AND SPONTANEOUS REWARMING OF DOMINANT AND NON-DOMINANT HAND

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INTRODUCTION

During outdoor occupations in winter, contact with cold materials can usually happen. Contact with materials with high thermal conductivity induces rapid skin cooling in contact areas. The decrease of skin temperatures in hands and fingers causes the deterioration of manual performance (1). Some of the literature concerning finger or hand cooling are reported, for example, by Havenith et al. (2) and Chen et al. (3), but none reported the spontaneous rewarming of hands or fingers. The aim of this study was to determine hand and finger skin temperatures during rapid cooling by a contact with metal surface and during subsequent spontaneous rewarming while the whole body was exposed to the cold when subjects were normothermic or cooled. Furthermore, we examined the effects of cooling and spontaneous rewarming on the bilateral differences in skin temperatures of hands and fingers.

METHOD

Six young men (mean ± SEM, age 25 ± 1 yrs, height 178 ± 2 cm, weight 73.4 ± 2.6 kg and body fat 14.4 ± 1.1 %) were served as test subjects. They were wearing winter clothing with 2-layered gloves and boots with a felt liner. The mass of the clothing was 3.2 kg without boots (mass 2.7 kg). Each subject attended 2 kinds of experiments. The first one was an experiment of **contact cooling**. When a subject entered the climatic chamber at -10°C with standing position, he gripped a steel bar (-10°C) in one hand for the first 10 minutes. After releasing the cold bar, he continued to stand still with the hands held beside the body. Then, at the 30 minutes, he held the steel bar in the opposite hand for 5 more minutes and released. The subjects used about 20% of their maximal voluntary contraction to hold the bar (diameter 35mm), of which the surface temperature was measured near the hand. Half of the subjects started by holding the metal bar with their right hand and the rest started with their left hand. In every subject the right hand was the dominant one. Another experiment was conducted with subjects standing still in the cold (-10°C) for 40 minutes without any contact (**air cooling**).

Rectal temperature (T_{re}) and skin temperatures (15 sites) were measured continuously and stored (Squirrel 1200, Grant, England) every minute. The 15 sites of skin temperatures were: forehead, chest, back, forearm, thigh, leg, foot, and hands and middle fingers on both dorsal and palmar sides of both hands. Mean skin temperature (T_{sk}) was calculated by weighting the local 8 sites by representative skin areas according to the equation of Mitchell and Wyndham (4).

RESULTS

After 40 min of the cold exposure, T_{re} was 37.3 ± 0.11°C in air cooling and 37.3 ± 0.14°C in contact cooling and was not significantly different from those in pre-exposure. T_{sk} significantly decreased 5.6°C to 27.1 ± 0.40°C in air cooling and 5.3°C to 27.1 ± 0.52°C in contact cooling, while there were no differences in the rate of the whole body cooling between the 2 kinds of experiments.

Table 1 shows the cooling rates of hands and fingers both in air and during contact cooling in each period. The cooling rate of the first period in the air was about 3 times greater than that of the second period, because T_{sk} in air cooling decreased to 27.8 ± 0.47 (mean ± SEM) °C at 30 min of body cooling, and the cooling rate had slowed down by this time. The cooling rates of fingers in contact cooling were different between the first period and the second one but the rate of decreasing in palm skin temperature in the second period was as large as the first one.

Table 1 Cooling rates (°C/min) in air and in contact cooling during 0 - 5 min and 30 - 35 min. The values are means and SEM of 6 test subjects.

	First contact period 0 - 5 min		Second contact period 30 - 35 min	
	mean	SEM	mean	SEM
Cooling rate (°C/min) in air				
Hand	0.74	0.06**	0.21	0.04
Palm	0.70	0.15**	0.22	0.03[b]
Finger (dorsal side)	1.20	0.12**	0.37	0.07
Finger (palmar side)	0.91	0.12**[b]	0.34	0.15[a]
Cooling rate (°C/min) in contact cooling				
Hand	0.56	0.11	0.10	0.10
Palm	1.37	0.26	1.42	0.12
Finger (dorsal side)	1.20	0.10**	0.56	0.11
Finger (palmar side)	1.89	0.23**	1.31	0.21

** differs significantly ($p < 0.01$) from second period of cooling rate.
[a] differs significantly ($p < 0.05$) from the cooling rate in contact cooling.
[b] differs significantly ($p < 0.01$) from the cooling rate in contact cooling.

Contact cooling had no significant effect on skin temperatures on the dorsal side of hands and fingers in both periods. The rate of skin cooling was about 2 times higher

in normothermic subjects (first period) and was 4 - 6 times higher in cooled subjects (second period) compared with cooling by cold air alone.

The result of cooling and rewarming rates in contact cooling are shown separately in the dominant and non-dominant hands in Table 2. The first and second contact cooling periods are pooled together. The cooling rate of hands and fingers showed no difference between the dominant and non-dominant hand. However, the rewarming rate of the palm and fingers on the palmar side after the release of the steel bar tended to be larger in the dominant hand than that in the non-dominant hand ($0.05 < p < 0.1$). Finger skin temperature on the dorsal side in the dominant hand rewarmed more rapidly than the opposite hand. No rewarming was found on the dorsal side of fingers and hands in the non-dominant hand.

Table 2 Cooling and rewarming rates (°C/min) of the dominant and the non-dominant hands in the experiment of contact cooling. The values are means and SEM of 6 test subjects.

	Dominant hand		Non-dominant hand	
	mean	SEM	mean	SEM
Cooling rate (°C/min) during contact cooling				
Hand	0.41	0.15	0.24	0.15
Palm	1.42	0.23	1.37	0.17
Finger (dorsal side)	0.79	0.15	0.97	0.21
Finger (palmar side)	1.51	0.24	1.76	0.30
Rewarming rate (°C/min) after contact cooling				
Hand	-0.32	0.09	-0.56	0.09
Palm	0.58	0.15	0.17	0.25
Finger (dorsal side)	0.44	0.45*	-0.58	0.10
Finger (palmar side)	1.24	0.42	0.24	0.23

* differs significantly ($p < 0.05$) from the non-dominant hand.

CONCLUSIONS

The results of the study indicate that the effect of contact cooling was even higher during the second contact cooling period in finger temperature. Skin temperatures on the dorsal side were not influenced in contact cooling. The dominant and the non-dominant hand showed different rewarming behavior after releasing the cold steel bar. This could be explained by functional (both neural and circulatory) differences in dominant and non-dominant hands shown by Treffel et al. (5). However, due to the

small number of test subjects further investigation is required to confirm these observations.

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