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Accumulation of Sweat in Clothing During Interval Exercise in Cold Environment

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Summary

In cold environment (-15 ^{o}C, air velocity 2.5 m/s) interval exercise with exercise/rest periods of 30/30 minutes caused greater accumulation of sweat into clothing during a 120 minutes exercise/rest protocol as compared to 10/10 minutes exercise/rest protocol. The amount of sweating, body temperature and physiological strain were comparable in the two protocols. These findings suggest that the evaporation of sweat from clothing during prolonged interval exercise in cold environment can be an important factor affecting thermal protection.

Introduction

In cold environment accumulation of sweat into clothing can compromise its thermal insulation (1). In normal conditions clothing is reduced during the working phases and increased when resting. During military exercise the phases of physical work and rest can change so rapidly that it is not possible to adjust the amount of clothing. This can lead to excessive sweating during the working phases followed by excessive body cooling during the pauses in physical work.
The aim of this study was to find out if the duration of exercise/rest periods affect the accumulation of sweat into clothing during interval exercise in cold environment with pauses spent in warm environment.

Methods

The exercise/rest periods were either 10/10 minutes or 30/30 minutes, and the total duration of the protocol was 120 min. The subjects participated in the two protocols in random order and the experiment sessions were separated at least by three days. Exercise (walking 6 km/h on treadmill, slope 2 ^{o}) was performed in cold environment (-15 ^{o}C, air velocity 2.5 m/s). The resting periods were spent sitting at +10 ^{o}C, air velocity 0.2 m/s, with the same clothing as during exercise.

The subjects were 7 voluntary healthy young men. Their basic characteristics are shown in Table 1. Before entering this study their physical work capacity was determined by measuring the maximal oxygen uptake on treadmill. They were wearing Finnish military winter clothing (M91, thermal insulation about 2 clo) and rucksack (12 kg). During the rest periods drinking of water was allowed *ad libitum*.

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Table 1.
Basic characteristics of study subjects.

Subject	Age years	Height cm	Weight kg	VO_2max ml/kg/min
1.	24	179	62	59
2.	23	175	69	53
3.	23	182	66	60
4.	20	183	68	54
5.	29	178	87	44
6.	28	183	97	40
7.	24	183	71	52
Mean	24.4	180.4	74.1	51.7
SE	1.2	1.2	4.8	2.8

VO_2max = maximal oxygen uptake
SE = standard error of mean

Skin and deep body temperature were measured continuously (YSI 400-series thermistors and Squirrel 1200, Grant, UK) and heart rate was registered (Sport Tester, Polar Electro, Finland) during the whole protocol. Oxygen consumption was measured for five minutes during the last exercise period (Medikro 901, Medikro Oy, Finland). The amount of ingested fluid was measured. The subjects were weighted (Mettler ID1, Germany) without clothing before and after the protocol. The amount of sweating was calculated as the reduction in weight during the protocol added by fluid intake and reduced with metabolic weight loss. Clothing was weighted before and immediately after the exercise protocol and the accumulation of sweat into clothing was calculated as the increase in its weight. Data are given as mean ± SE. Paired T-test was used to compare the 10/10 and 30/30 minutes protocols. The study was approved by the Ethics Committee of the Institute of Occupational Health.

Results

The amount of sweating was comparable during the 10/10 protocol and the 30/30 protocol. The accumulation of sweat into clothing was lower ($p< 0.05$) after the 10/10 protocol than after the 30/30 protocol (Table 2). The fluid intake was greater ($p= 0.01$) during the 10/10 protocol than during the 30/30 protocol. The mean skin temperature, deep body temperature, mean body temperature as well as forehead and cheek temperature were comparable during the 10/10 and 30/30 protocols (Table 3).

At the end of the last exercise period oxygen consumption was 33.5 ± 0.9 ml/min/kg in the 10/10 protocol and 32.4 ± 3.8 ml/min/kg in the 30/30 protocol (ns). During the exercise periods heart rate was in average 150 beats/min in both protocols.

Table 2.
Sweating, accumulation of sweat into clothing and fluid ingestion during 10/10 and 30/30 minutes interval exercise protocols.

	10/10 min	30/30 min	p
Sweating (g)	809 ± 118	777 ± 81	ns
Accumulation of sweat into clothing (g)	353 ± 28	392 ± 32	0.018
Fluid ingested (ml)	457 ± 121	141 ± 41	0.010

mean ± SE, ns = not significant

Table 3.
Body temperatures during 10/10 and 30/30 minutes interval exercise protocols.

Temperature	10/10 min	30/30 min	p
Mean skin (°C)	31.7 ± 0.2	31.3 ± 0.3	ns
Deep body (°C)	37.5 ± 0.1	37.5 ± 0.1	ns
Mean body (°C)	35.5 ± 0.1	35.4 ± 0.1	ns
Forehead (°C)	27.6 ± 1.6	29.8 ± 0.7	ns
Cheek (°C)	21.8 ± 1.4	22.1 ± 0.9	ns

mean ± SE, ns = not significant

Discussion

Physical work in cold environment requires clothing that is a compromise between sufficient thermal protection and body cooling. Normally in cold conditions an exercising subject reduces clothing and adjusts the pace of work in order to avoid excessive sweating. During resting periods additional clothing is added to guarantee thermal comfort. However, during military exercise the changes between physical work and rest can be so rapid and unpredictable that any adjustment of clothing is impossible. Moreover, military clothing has also other protective purposes than thermal protection. In that kind of situation thermal protection is often preferred leading to the fact that the thermal insulation of clothing is excessive during the exercise phases. This is followed by excessive sweating compromising the thermal insulation.

In the present study our aim was to find out if there are differences in sweating and accumulation of sweat into clothing during different types of interval exercise in cold environment. The observed differences can help to recognize and quantify the sweat accumulation problem as well as point out the characteristics of clothing which need further development. Our subjects had clothing with thermal insulation of about 2 clo. That is clearly greater than the calculated need of thermal insulation in our study conditions, which is 0.8 clo during the exercise phases and 1.6 clo during resting periods (ISO/TR 11079).

We compared the 10/10 minutes exercise/rest protocol to the 30/30 minutes exercise/rest protocol, both lasting for 120 minutes. It is evident that physiological strain was comparable in both protocols. The fluid intake was greater during the 10/10 protocol. Possibly the greater number of resting periods during the 10/10 protocol gave better opportunity for fluid ingestion which was allowed *ad libitum*. However, the amount of sweating was not significantly different in the two protocols. Thus it seems that the lower fluid intake during the 30/30 protocol did not lead to such hypohydration that would have reduced sweating (2-4). The accumulation of sweat into clothing was significantly greater during the 30/30 protocol. This seems to result from reduced evaporation during the 30/30 protocol, because there was no significant difference in sweating. The total durations of cold (exercise) and warm (rest) periods were similar in the two protocols. However, the longer continuous period in cold (30 minutes) could have lead to condensation of sweat into the clothing reducing the capacity of evaporation. In conclusion, our findings suggest that the evaporative function of clothing can become an important factor affecting thermal protection during prolonged interval exercise in cold conditions.

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