THERMAL RESPONSES AND PHYSICAL STRAIN IN MEN WEARING PROTECTIVE CLOTHING IN THE COLD

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INTRODUCTION

Nuclear, biological and chemical (NBC) protective clothing is necessary to protect the wearer from the contaminated environment in all temperature conditions. The use of NBC clothing increases the physical and thermal strain due to its high water vapor resistance, weight, bulkiness and whole body cover. The heat load and work performance in warm and hot conditions is widely reported in literature (e.g. 1,2), but studies while wearing NBC clothing in cold are not reported to our knowledge. The aim of this study was to assess the thermal responses and physical strain arising while wearing NBC overgarment during a long term work/rest cycle in cold conditions.

METHODS

Six healthy men (mean ± S.D, age 22.8 ± 3.6 yrs, weight 74.3 ± 7.7 kg, height 179.3± 3.8 cm and body fat 15.6 ± 1.7 %) participated in the *study*. The subjects performed work/rest cycles (see below) during eight hours at an ambient temperature of -10°C wearing an impermeable rubber suit (IP) or a semipermeable activated carbon suit (SP). Underneath the overgarment the subjects wore conventional middle layer and underwear with long sleeves and legs. Socks, rubber boots with felt liners, cotton gloves under the rubber gloves and face mask were also worn. Leather mittens were used during the last 30 min of each rest period.

Each experiment comprised 4 work/rest cycless, for a total duration of 8 hours. The work and rest periods in each cycle lasted 1 hour each. The experiment started with the work period. Exercise was performed by stepping on the bench of 20 cm height 15 times per minute.

Rectal temperature (T_{re}) and skin temperatures from 12 sites were measured and registered every minute by a portable data logger (Squirrel 1200, Grant, England). Mean skin temperature (T_{sk}) was calculated by weighting the local skin temperatures by representative skin areas. Body heat content was calculated by the equation: (Q = 3.48 * body weight (kg) * ($0.65*T_{re}+0.35*T_{sk}$). Heart rate was recorded telemetrically at one minute intervals (Sport Tester, Polar Electro, Finland). Oxygen consumption (VO_2) was measured (Medikro 202 Ergospirometer, Finland) during the last 10 min of the third work and rest cycles. Weights of subjects (nude and clothed) and every layer of clothing were determined before and immediately after the experiments.

RESULTS

The energy cost was 283 $W \cdot m^{-2}$ during work while wearing IP. This is 13% higher than in the SP ensemble. During rest periods V02 was 30 % higher in IP than in SP.

T_{re} increased during work cycles but decreased during rest cycles, with an overall trend to decrease towards the end of the experiment in both protective clothing ensembles during the 8 hours cold exposure (Fig.1). T_{re} was significantly higher in SP during 2nd and 3rd work periods compared to IP.

After the initial decrease. mean skin temperature (T_{sk}) stabilized during the first work period (Fig. 1). During work periods 2 to 4 T_{sk} increased about 2°C for both NBC ensembles. T_{sk} was significantly higher in SP than in IP. Body heat content dropped during the 1st rest period by 7 and 5-6 $kJ \cdot kg^{-1}$ from the initial value for IP and SP, respectively and variated by 4 kJ/kg during work/rest cycles. Finger skin temperature fell rapidly during each rest period (Fig. 2). The use of mittens slowed the decrease only temporarily. Skin temperature in the hands decreased gradually to 14 and 16°C in IP and SP, respectively. Foot temperature followed the Same pattern, but remained above the discomfort level.

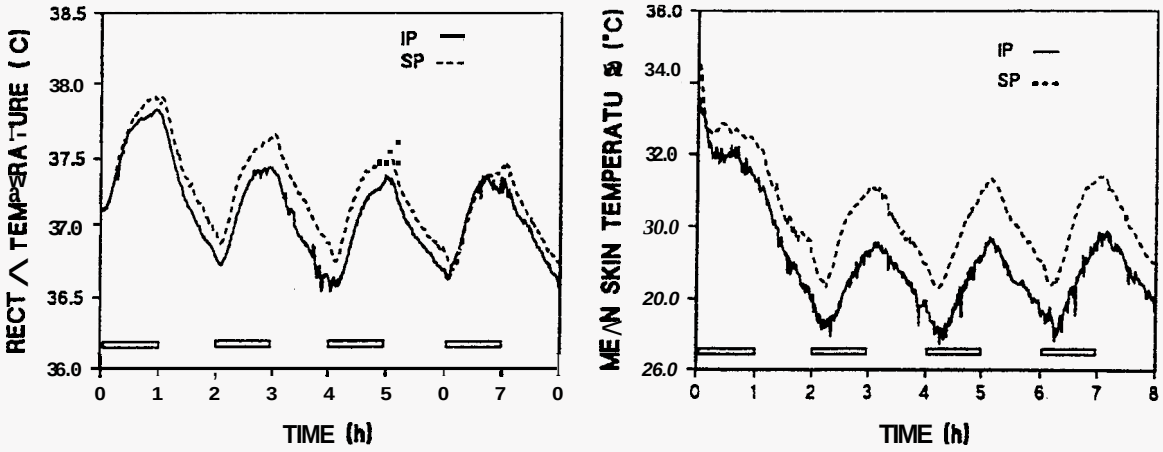

Figure 1. Rectal and mean skin temperature during the 8 hours work/rest cycle in impermeable (IP) and semipermeable (SP) ensembles at -10°C. Bars indicate the work periods. (n=6).

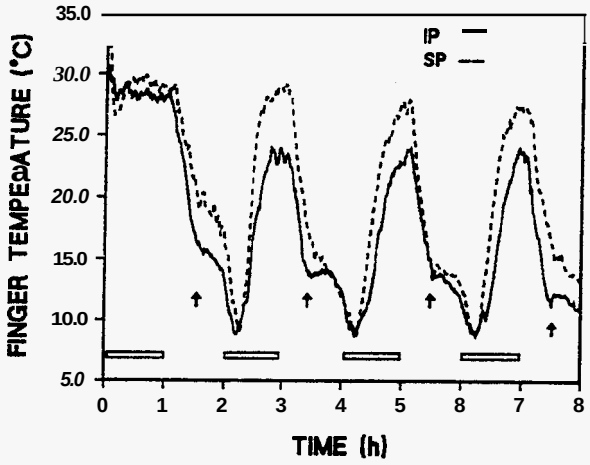

Figure 2. Finger skin temperature at -10°C. Arrows indicate the adding of the mittens. (n=6).

CONCLUSIONS

Rectal temperature showed variation according to work/rest cycles and decreased towards the end of the experiment. Although mean skin temperature varied within each of the last 3 work/rest cycles, there was no overall decline towards the end. During rest periods the extremities, especially fingers and hands, cooled rapidly causing serious discomfort. According to Lotens (3) skin temperature in hand and finger lower than 15°C is considered to cause performance degradation.

In conclusion, NBC protective clothing can be used for long periods in cold conditions during moderate work load. However, body heat content decreased markedly during the rest periods. The most serious concequence is the rapid cooling of the fingers and hands to the level of discomfort and performance degradation.

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