THE INFLUENCE OF LOCALISED AUXILIARY HEATING ON HAND COMFORT DURING COLD EXPOSURE

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INTRODUCTION

Military personnel are often required to perform delicate work in extreme cold (e.g., repair or maintenance of vehicles, weapons and equipment; treatment of wounds; etc.). This frequently necessitates the removal of protective mitts in favour of working with gloved or even bare hands. Exposure of the hands to such conditions can result in rapid cooling of the extremities, a loss of manual dexterity, and an increased risk of cold injury. Auxiliary heating of the hands with electrically heated gloves has been attempted in the past but has generally been unacceptable. The addition of heating elements to the gloves increases the stiffness in the fingers, thereby hampering dexterity, and the robustness of the heating elements to repeated flexing in the cold can be a problem. The direct heating of the hands and fingers is also an inherently inefficient process because much of the added energy is lost to the environment through the thin insulation of the gloves. Numerous studies in the past have looked at the effects of applying local auxiliary heat (using various parts of the body) on hand comfort (1.2). However, most of these studies were done in a thermoneutral or cool environment (no less than about 14°C). To the authors' knowledge, only two studies have looked at the effects of auxiliary heat on hand comfort (while barehanded) during cold exposure. Auxiliary heating of the forearms while exposed to a -18.5°C ambient environment has been found to be unsuccessful in maintaining hand comfort (3). Rapaport et al. (4) on the other hand found that hand comfort could be maintained for a one hour period while exposed to an ambient temperature of -34.4°C with the use of a full-body air-heated suit. However, such a suit is impractical for field.

The present study investigated the effect of torso heating on hand comfort and body heat transfer during exposure to -15°C air. The working hypothesis was that heating the torso may result in the circulation of blood to the extremities to dissipate the extra heat. In turn, warming of the extremities may be achieved.

METHODS

Six healthy male subjects between the ages of 21 and 35 years were exposed one week apart to two tests, randomly assigned, in addition to a familiarization run. The two tests consisted of a control test (CT) and a heating test (HT). During the tests the subjects wore the first two layers of new Canadian Forces (CF) arctic clothing ensemble and an electrically heated vest and sat in a cold chamber for a period of 3 hours while exposed to an ambient temperature of -15°C (wind~2km/h). Upon entering the chamber (barehanded), the subject's finger temperature was monitored until it reached 15°C, at which point the subject was asked to put on a pair of CF arctic mitts (CT) or the electrically heated vest worn by the subject was turned on (HT). The beginning of the treatment was defined as time "zero" (t_0). The skin under the heated vest was kept at 42°C by adjusting the power to the heaters. During the 3 hrs of exposure, the following parameters were measured: rectal temperature (T_{re}), whole-body mean weighted skin temperature and heat flow ($\overline{T}_{sk}$, $\overline{H}$) (using Hardy and DuBois 12 point system); mean skin temperature and heat flux of the two middle fingers ($\overline{T}_{fing}$, $\overline{H}_{fing}$) and mean skin temperature of the two large toes ($\overline{T}_{toe}$). In addition, mean skin temperature and heat flow from the torso ($\overline{T}_{torso}$, $\overline{H}_{torso}$) were measured under each of the ten heaters that were fixed around the subject's torso. Statistical analyses were based on the time period between time -10 to 120 min. (n=6). Past the 120 min mark, n<6.

RESULTS

There was no significant difference (p>0.05) between CT and HT conditions for the 10 min period prior to t_0 for all the measured parameters. The following data are presented as Mean±S.E. for the time period t_{-10} to t_{120} where n=6. In CT, $\overline{T}_{fing}$ increased for the first 7 min and then decreased to 12.7±.03°C by t_{50}, at which point it leveled off (Fig. 1). During HT, there was a rapid increase in $\overline{T}_{fing}$ (after a 4 min lag time) until 25.9±1.2°C was reached at t_{50}. $\overline{T}_{fing}$ was relatively constant until t_{90}, decreased from 26.3±2.1°C to 23.2±2.5°C from t_{90} to t_{100} and stabilized again for the last 20 min. In CT, T_{re} decreased from 37.15±0.08°C to 36.71±0.21°C over the 120 min period that the mitts were worn, whereas during HT, T_{re} was 37.16±0.07°C at t_0, rose to a peak of 37.28±0.08°C at t_{40}, and then gradually decreased to reach 37.18±0.10°C at t_{120}, although the changes were not statistically significant (p>0.05) (Fig. 2). In the past, it has been reported that electrical heating of the hands alone may induce insidious hypothermia (5). Based on the stable T_{re} observed in our study, there does not appear to be any risk of insidious hypothermia when torso heating is applied for short durations (up to 3 hours). In CT, $\overline{T}_{toe}$ continued to decrease until a value of 12.8±0.6°C was reached after wearing the mitts for 120 min, whereas during HT, $\overline{T}_{toe}$ continued to decrease until a value of 21.7±2.6°C was reached after 120 min. In CT, $\overline{T}_{sk}$ continued to decrease until a $\overline{T}_{sk}$ of 27.4±0.4°C was reached after 120 min. During HT, $\overline{T}_{sk}$ increased for the first 10 min and then decreased until a $\overline{T}_{sk}$ of 30.3±.3°C was reached after 120 min. In CT, $\overline{H}_{fing}$ decreased to 42±11 W/m² by t_{20} and leveled off for the last 100 min that the mitts were worn. During HT, $\overline{H}_{fing}$ continued to increase until 917±101 W/m² was reached at t_{40}. A relatively constant $\overline{H}_{fing}$ was maintained from t_{40} to t_{100}, decreased from 849±58 W/m² to 687±54 W/m² from t_{100} to t_{105} and then stabilized again for the last 15 min. In CT, $\overline{H}$ decreased to 159±5 W by t_{20}, at which point it leveled off, whereas during HT, $\overline{H}$ decreased to 88±8 W by t_{30} and then leveled off.

It should be noted that 5 out of the 6 subjects remained in the chamber for a treatment period greater than 120 min (up to 170 min of treatment) during which time the general trend for the parameters in HT and CT remained the same. All the parameters measured were significantly higher in the heating condition (with the exception of $\overline{H}$, which was significantly lower) relative to the control condition ($p<0.05$) starting at the following times (in minutes): $\overline{T}_{fing}$: 17; T_{re}: 27; $\overline{T}_{toe}$: 47; $\overline{T}_{sk}$: 2; $\overline{H}_{fing}$: 2; $\overline{H}$: 2. The heater power (voltage x current) required to maintain $\overline{T}_{torso}$ at 42°C decreased from 115±5W to 103±5W from time 35-120 min. However, due to the loss of some heat to the environment, the actual $\overline{H}_{torso}$ decreased from 75±4 W to 65±3 W over the same time period. The first 35 min period of heating was used to achieve a stable $\overline{T}_{torso}$ of 42°C.

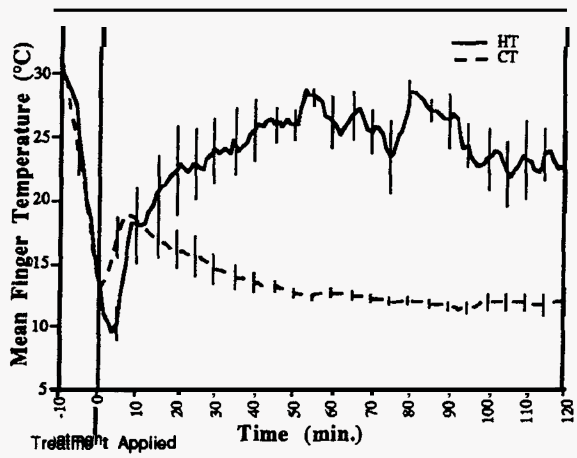

Fig. 1 Average of right and left middle finger temperature for t_{-10} to t_{120} at -15°C. (n=6) [Mean±S.E.]

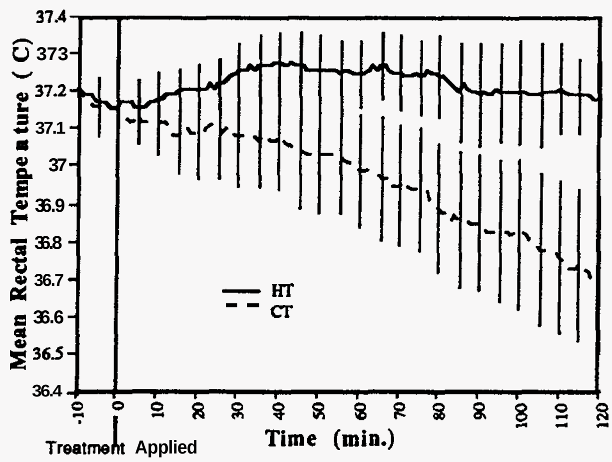

Fig. 2 Average rectal temperature for t_{-10} to t_{120} at -15°C. (n=6) [Mean±S.E.]

CONCLUSION

The application of heat to the torso region of the body can maintain finger and toe temperature at a comfortable level for an extended period of time during cold exposure. The local effects of cold on barehands can be overcome provided that there is sufficient heat supplied to the torso.

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