FACE PROTECTION DURING COLD AIR EXPOSURE LIMITS FINGER COOLING AND IMPROVES THERMAL COMFORT

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INTRODUCTION

When people dress for cold weather the face is often left exposed to the cold, despite adequate insulation over the rest of the body. Facial protection may be neglected for practical reasons, such as difficulty accommodating a balaclava under other headwear, or for personal reasons, such as not liking the appearance, but it also may be overlooked because facial skin temperatures are better maintained than most other regions of the body (7) and face cooling may be better tolerated due to familiarization. However, facial cooling causes a reflex vasoconstriction that reduces extremity blood flow (4-6). This reduced blood flow may contribute to the decreased hand and finger temperatures which are associated with degraded manual performance and increased risk of peripheral cold injury during cold exposure (1).

The purpose of this study was to test the hypothesis that limiting the degree of facial cooling during whole-body cold air exposure by wearing a balaclava and goggles would reduce the stimulus for extremity vasoconstriction, resulting in higher extremity temperatures, compared to a bare face. This hypothesis was tested under conditions likely to cause reductions in extremity temperatures while limiting risk of frostbite when the face is exposed.

METHODS

Ten men participated in this study which was approved by the Institute Scientific and Human Use Review Committees. Each person volunteered after being informed of the purpose, experimental procedures, and known risks of the study. Investigators adhered to Army Regulation 70-25 and U.S. Army Medical Research and Materiel Command Regulation 70-25 on the Use of Volunteers in Research. The participants were 22.3±2.5 years old; 177.6±6.9 cm in height; had a body mass of 82.4±17.9 kg; and body fat 18.6±3.6 %.

Each volunteer completed two cold air exposure trials (-15°C, 3 m/s wind speed): one wearing a balaclava and goggles to protect the face from direct cooling, and another with the balaclava pulled down off the face and no goggles to expose the face to cold wind. The volunteers were dressed in cold-weather clothing with an insulation value of about 3 clo. Volunteers stood facing into the wind for 60 min. Core (esophageal or rectal) and skin (arm, chest, thigh, calf, cheek, hand, foot, finger) temperatures were measured every 10 seconds. Mean weighted skin temperature was based on arm, chest, thigh and calf temperatures. At 15 min volunteers removed mitts and, while wearing thin gloves, performed a Purdue Pegboard (PP) task that
requires fine dexterity. Data analysis for PP used the combined score of the average of peg placements (right hand, left hand, both hands) plus the score for assembly. They then put their mitts back on until 30 min, at which time they removed the mitts to perform a Minnesota Rate of Manipulation (MRM) task that requires gross hand dexterity. Data analysis for MRM used the combined score of the average of four times for placing blocks plus the time for turning blocks. They put their mitts back on once more until 50 min, at which time they completed the PP task immediately followed by the MRM task. This timeline is shown in Figure 1. Before beginning each dexterity task volunteers were asked to rate their thermal sensation and thermal comfort.

Before the experimental trials, volunteers practiced both dexterity tests 5-6 times in temperate conditions while wearing the thin gloves.

![Timeline of cold exposure and dexterity tasks.](image)

**RESULTS**

The clothing configurations on the two trials are shown in Figure 2, along with the skin temperatures after 50 min cold air exposure. All temperatures fell (p<0.05) during cold exposure. Cheek and hand temperatures were lower (p<0.05) on CON, compared to BAL. Thermal sensation (TS) and thermal comfort (TC) scales are shown in Figure 3, along with data for each trial at 15 min and 50 min cold exposure. Both TS and TC were better (p<0.05) during BAL (cool; slightly uncomfortable) than during CON (cold; uncomfortable).
Figure 2: Clothing configurations for the Balaclava and Control trials, and skin temperatures after 50 min cold exposure.

<table>
<thead>
<tr>
<th>Temperatures, °C</th>
<th>Balaclava Trial</th>
<th>Control Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 50 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheek*</td>
<td>25.6±2.6</td>
<td></td>
</tr>
<tr>
<td>Mean Weighted</td>
<td>31.0±0.6</td>
<td></td>
</tr>
<tr>
<td>Hand*</td>
<td>23.4±2.7</td>
<td></td>
</tr>
<tr>
<td>Finger</td>
<td>15.0±3.5</td>
<td></td>
</tr>
<tr>
<td>Foot</td>
<td>21.4±2.6</td>
<td></td>
</tr>
</tbody>
</table>

* indicates significant difference compared to Control

Figure 3: Thermal sensation and thermal comfort scales, with data shown for each trial after 15 min and 50 min cold exposure. * indicates significant difference (p<0.05) compared to CON.
Finger temperatures during cold air exposure are shown in Figure 4. In the first 15 min of cold air exposure as participants stood still facing the wind, finger temperature decreased less (p<0.05) when wearing the balaclava (2.6°C), compared to the bare face (4.9°C). The difference between trials became the greatest after 30 min cold exposure when finger temperatures on BAL were 4.1°C warmer than CON. However, at the end of the trial, and after removing mitts to complete back-to-back dexterity tasks, finger temperatures were similar on both trials.

Manual dexterity on the PP fine dexterity task was poorer (p<0.05) after 50 min cold exposure (15±3 units), compared to both the final practice (with gloves, but no cold exposure; 20±3 units) and 15 min cold exposure (18±3 units), but there were no differences between trials. There was no statistically significant difference in performance on the MRM task due to cold exposure (100±11 sec during practice; 108±13 sec at 30 min cold exposure; 113±2 sec at ~55 min cold exposure), nor was there any difference between trials.

Figure 4. Finger temperatures during cold air exposure. PP: finger temperature at the end of the Purdue Pegboard task (4-5 min); MRM: finger temperature at the end of the Minnesota Rate of Manipulation task (7-8 min); PP-MRM: finger temperature at the end of both tasks combined (12-15 min). Dashed lines are drawn at temperatures associated with discomfort (20°C); impaired manual dexterity (15°C); and loss of tactile sensitivity (8°C).
CONCLUSIONS

Wearing a balaclava and goggles to protect the face from direct cooling was effective for blunting the fall in finger temperatures during 30 min cold air exposure at -15°C with 3 m·s⁻¹ wind speed. Thermal sensation and thermal comfort were also better when wearing the balaclava, compared to a bare face. However, repeatedly removing mitts to perform manual dexterity tasks ultimately eliminated the initial difference in finger temperatures afforded by the balaclava. This explains why the higher overall finger temperatures on the BAL trial were not associated with better manual dexterity. At the time of the initial Purdue Pegboard test, finger temperatures on both trials were above the 15°C skin temperature at which manual dexterity degrades (2), and performance was no different than baseline measurements made at a normal room temperature while wearing gloves. At the time of the second Purdue Pegboard test, finger temperatures on both trials had fallen well below 15°C, and performance on that task was degraded on both trials. Performance on the Minnesota Rate of Manipulation task did not significantly change during cold exposure, most likely because it requires gross manual dexterity, and hand temperatures were above 20°C even at the end of cold exposure.

In both conditions, mean skin temperature fell to 31°C, a skin temperature associated with reflex vasoconstriction and with thermal discomfort, even when the face is not cooled (3). Indeed, finger temperatures decreased even when subjects wore the balaclava, although at a slower rate (0.17°C·min⁻¹), compared to the control trial (0.33°C·min⁻¹). If subjects had not experienced local cooling when they removed their mitts to perform dexterity tasks, these rates of cooling may have persisted. In that case, by the end of the 60 min cold exposure finger temperature would be 23.0°C with the balaclava and 13.8°C with a bare face. This would be an important difference in finger skin temperatures, both for thermal comfort and for manual dexterity.

REFERENCES