PROTECTION FROM GLOVE AGAINST CONTACT COOLING

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INTRODUCTION

When work is performed in a cold environment, usually gloves are required and provided. The selection of appropriate gloves depends on several factors such as the actual temperature, glove type, performance and type of work. The thermal protection provided by the gloves should comprise the protection from both convective cold and contact cold. Recently, several reports about hand contact with different cold surfaces with or without gloves have appeared in the literature (1, 2). None of the reports have described the local thermal responses of the gloved hand in contact with a cold surface. The European standard EN 511 provides tests and classification of resistance to convective and contact cooling, respectively. However, the basis for classification levels has been poorly validated in studies of human thermal reactions using gloves in the cold.

The present study investigated the skin temperature change of the protected hand in contact with different cold metal surfaces. Five different gloves were compared regarding their thermal protection against cold contact.

METHODS

A mini hot plate (MHP) (3) was used to test the contact thermal resistance of the gloves and a heated full scale thermal hand (TH) (4) was used to test the convective thermal resistance of the gloves.

Five different kinds of working gloves were chosen. Glove A was made of 100% cotton in a single layer. Glove B was made of grain from pig and half lined on the palm side and some cotton materials on the back of the glove between the leather. Glove C was knitted with 100% wool in a single layer. Glove D was made of grain from sheep with an artificial fur liner as the insulation layer. Glove E was made of grain from pig with an artificial fur liner as the insulation layer. Table 1 gives the resistance values against convective and contact cooling of the five gloves. The performance level in the table indicates the classification according to EN 511.

Table 1. The thermal resistance of the experimental gloves.

Glove	Weight (g)	Contact resistance m² °C/W	Contact resistance Perf. level	Convective resistance m² °C/W	Convective resistance Perf. level
A	9.1	0.021	0	0.050	0
B	70.9	0.043	1	0.113	1
C	39.8	0.046	1	0.080	0
D	142.2	0.052	2	0.167	2
E	93.2	0.084	2	0.182	2

Seven subjects (4 females and 3 males) volunteered for the experiments. A printed instruction was given to the subjects and they had the right to withdraw whenever they wanted. Skin temperature was measured at the finger pad of the index finger in the contact area (T_{cont}) with a small, fast responding thermocouple. The local cold exposure was conducted in a small chamber which was placed in a laboratory at room temperature. The air was cooled by liquid carbon dioxide evaporation in the chamber. The air temperature in the chamber could be maintained with a precision of ±1°C. An 11 cm aluminium cube was put inside the small chamber and its temperature was equivalent to the air temperature. The aluminium surface temperature and the air temperature beside the cube were measured simultaneously. All the temperatures were recorded with thermocouples (J type).

After recording all the temperatures for one minute, the subject was asked to insert his or her left hand into the small chamber and press the metal cube surface with the index finger. The temperatures were recorded once per second, progressively slowing down to 1 record in 8 seconds. The aluminium cube was put on a balance to control the contact pressure. The cold exposure was stopped under the following circumstances: 1) when the subject felt very cold, very much pain, or felt tired; 2) when the skin temperature on the finger reached 0 °C, or 3) after 15 minutes of contact.

The experiment was a three-factorial design. The three factors were glove (A, B, C, D, E); cube surface temperature (T_{sm} at -7, -14 and -21 °C) and contact pressure (0.98, 5.8 and 9.8 N). The multiple ANOVA analysis was performed using the skin temperature of the contact area (T_{cont}) after 1, 5 and 10 minutes of cold exposure.

RESULTS AND DISCUSSION

Gloves, T_{sm} and Pressure had significant effects on T_{cont} at 1, 5 and 10 minutes ($p<0.05$). Significant interactions between Glove and T_{sm}, and between Glove and Pressure were found for T_{cont} at 1 minute. The multiple range test of variance was used to specify the pairwise comparisons between means for the different levels of each factor. Table 2 shows the differences between the factor levels.

Table 2. The significant differences between the factor levels for all the dependent variables.

Dependent variables	Gloves	T_{sm} (°C)	Pressure (N)
T_{cont} 1 min	A, B, C, DE*	-21	0.98
T_{cont} 5 min	A, BC*, DE*,	-21	0.98
T_{cont} 10 min	A, BC*, DE*	-21	0.98
D_t**	A, BC*, DE*	-7	0.98

e.g.: BC* and DE* means that there was no significant differences between glove B and C, or D and E, but both of them differed significantly from the others.
** D_t represents the duration of contact.

The analysis indicated that under all the conditions, glove A was very different from the others (poor protection). Glove B and C had quite similar capacity for protection against cold contact, as well as D and E. The contact pressure of 5.8 and 9.8 N had no significantly different effect on the cold contact. The contact skin temperature was significantly higher with pressure of 0.98 N than with other two pressures. This indicated that a contact pressure higher than a certain level (might be lower than 5.8 N), did not increase the contact cooling. Touching -21°C metal surface with gloved hand, the skin temperature decreased significantly. There was no significant difference of the skin temperature decreasing between touching -7°C and -14°C metal surfaces.

The results showed that glove A provided poor protection at -7 °C. Almost in all the subjects, the contact skin temperature reached below 12 °C. Such a level is reported to impair the tactile sensitivity and manual dexterity (5, 6). Some of the subjects even ran the risk of frostnip injury (skin temperature was lower than 1 °C) (1). The glove A should not be used in a cold environment below -7 °C. Similarly, the gloves B and C provided poor protection from -7 to -14 °C. In many of the subjects the contact skin temperature reached below 12 °C within 9 minutes of contact with a pressure higher than 5.8 N. The results indicated that glove B and C can be used in a cold environment at -7 to -14 °C, if work time is shorter than 5 minutes. Gloves D and E provide protection down to -14 °C. At -21 °C, the contact skin temperatures of most subjects decreased below 12 °C within 15 minutes.

CONCLUSION

Glove type, pressure and temperature significantly affected the cooling of the finger. Results from wear trials indicated good agreement with the ranking achieved by the gloves in technical tests. More glove types and more wear conditions are needed to fully verify the relevance of the EN 511 classification system.

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