

EFFECTIVENESS OF WATERPROOF, BREATHABLE HANDWEAR IN A COLD ENVIRONMENT

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INTRODUCTION

Cooling of the *hands* has been implicated as a cause for reduced endurance time, loss of manual dexterity and general discomfort during cold exposure. An extended exposure to cold-wet weather can result in rapid cooling of the extremities from the conduction of heat through wet layers of insulation. Historically, military campaigns conducted in cold-wet conditions have resulted in a high incidence of immobilizing cold injuries to ground troops wearing clothing incapable of providing adequate insulative and moisture protection relative to the combat theater. In a questionnaire given to 2000 United Kingdom troops immediately following the Falkland Islands War in 1982, cold hands were recorded as one of the three major medical problems during all ground operations (1). The purpose of this present study was to evaluate physiological responses when subjects wore waterproof, breathable handwear while sitting and exercising in a cold environment. Specifically, the study was designed to show if the handwear would meet certain performance requirements and provide adequate protection to military personnel wearing a recently-developed cold weather clothing system.

METHODS

Eight subjects each wore a leather work glove that incorporated either a polytetrafluoroethylene (PT), polyethylene (PE) or polyurethane (PU) membrane. The total thermal resistance, I_t ($m^2 \cdot K \cdot W^{-1}$) of the four layers of materials that comprised the entire glove (separate polyester inner glove, and the actual work glove which utilized a nylon micot-faced foam liner, the membrane liner, and a leather outer shell) when measured on a thermoregulatory model of the human hand was similar for all test gloves ($I_t = 0.150$). Subjects wore an extended cold weather clothing system (ECWCS, $I_t = 0.561$, total evaporative resistance, R_{et} [$m^2 \cdot kPa \cdot W^{-1}$]= 0.082 when measured on a thermal manikin) that utilized three synthetic, hydrophobic inner layers and one waterproof, breathable outer layer containing PT. Testing was conducted in a cold environment ($-9.5^\circ C$, 20% r.h.) with subjects who wore dry gloves while sitting on a bench (S1), walking with dry gloves on a treadmill at $0.98 m \cdot s^{-1}$ (W1), sitting with wet gloves (S2) or walking with dry gloves in an air velocity of $4.4 m \cdot s^{-1}$ (W2). Endurance time (ET, max = 120 min) was dependent on exposure responses and pre-set safety criteria. Rectal (T_{re}), middle finger (T_{mf}) and mean skin temperature (T_{sk} , 10 sites) were measured periodically.

RESULTS

Table 1. shows mean endurance times while wearing the test handwear during the four exposure conditions. ET was significantly lower ($p < 0.0005$) for all gloves during S2. ET was maximum when wearing dry PU but was reduced to the lowest ET (58 min) when the gloves were wet during S2. Several subjects reported a sensation of dampness within all three gloves during S2. The complete disassembly of PU gloves which were found to contain an inordinate amount of moisture at the completion of S2 revealed small tears in the actual membrane material. The fastest drop in T_{mf} also occurred during S2 (mean drop ranged from 0.26 to $0.30^\circ C \cdot min^{-1}$ for the three gloves). ET was greater during S2 when PE and PT were worn (74 and 83 min, respectively). Final T_{mf} and T_{sk} values during W1 were significantly higher than W2 values. There were no significant effects of glove type on final T_{re} and T_{sk} values.

Table 1. Mean values (8 subjects) of endurance time, ET (minutes, maximum=120) while wearing the three test gloves during the four exposure conditions.

Exposure Conditions	S1	W1	S2	W2
Glove	ET			
PT	107	120	83	120
PE	107	120	74	120
PU	120	120	58	120

CONCLUSIONS

These data show that a decrease in thermal resistance of wet handwear and a moderate wind affected physiological responses of subjects who wore gloves incorporating waterproof, vapor-permeable membrana. A protective membrane material which is claimed by a manufacturer to be "waterproof" and "breathable" can possibly be penetrated by moisture during a prolonged soak in water. Whether this is due to the particular physical characteristics of the actual membrane or to membrane damage during the manufacture of the glove cannot be fully concluded from these results. Currently, it is the manufacturers practice to test membrane inserts for leakage with an air inflation test immediately after their construction, before incorporation into a finished glove. Damage to the membrane during the glove assembly and the resulting ingress of water appeared to contribute to a reduction in endurance times with one of the test gloves in this study. Furthermore, the leather outer shell of the test glove absorbed a quantity of water during S2 which when combined with the relatively large surface area presented by a glove allowed for an increased degree of heat loss via conduction from the hand. Finally, the results suggest that a similar glove with a small increase in thermal insulation which is protected from environmental water contact by an undamaged PT or PE protective membrane would probably increase subject endurance times toward the desired maximum when wet and better complement the excellent cold-wet weather protective capabilities of the ECWCS ensemble.

DISCLAIMER

The views, opinions and/or findings in this report are those of the authors, and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation. Human subjects participated in these studies after giving their free and informed consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

REFERENCES

1. McCaig, R.H. and Gooderson, C.Y., Ergonomic and physiological aspects of military operations in a cold wet climate, *Ergonomics*, 29:849-857, 1986.