

## Canadian Forces Cold Weather Clothing Project

Effect of donning/doffing of the arctic parka at work during cold exposure on core, skin and clothing temperatures and on perceived levels of thermal comfort.

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### INTRODUCTION

The new Canadian Forces (CF) cold weather clothing ensemble was designed to protect the soldier in a variety of weather (extreme cold/wet cold) and work conditions. The clothing ensemble consists of an inner layer (fleece sweat shirt and pants), a middle layer (uninsulated polyester/cotton jacket and trousers with a Goretex drop lining) and an outer layer (insulated polyester/cotton parka and trousers with a Goretex drop lining). The inner and middle layers were intended for protection in the temperature range of -10 to +10° C, while the inner, middle and outer layer for temperatures between -10 to -40° C. It was also designed so that personnel in the field could don/doff the clothing to maintain thermal comfort on the basis of the "layer principle". As such, the effect of donning/doffing various layers on body temperature balance on the basis of coolness or warmth is a significant consideration. It was deemed important to determine if subjective feelings of coolness or warmth were enough to allow the wearer to keep in temperature balance by altering the clothing worn and at what core, skin and garment inner layer temperatures the donning/doffing occurred.

The purposes of this study were 1: to determine the effect of donning/doffing of the arctic parka on core and skin temperature while walking at a moderate intensity during cold exposure (-30°C), and 2: determine the "general" and "location specific" rating of perceived cold (RPC) at which the donning/doffing occurred and the concomitant body skin and garment inner layer temperatures.

### METHOD

**Subjects.** Two male and one female graduate students, well acquainted with our laboratory procedures, participated in the study. The subjects were between 20 and 30 years of age; and all had Body Mass Indexes (BMI) less than 26 Kg/m<sup>2</sup>. A written statement of voluntary consent was signed by the subjects.

**Materials.** The subjects were fitted with the new CF cold weather ensemble. The insulated trousers were not worn in this experiment, as they have been shown to be too bulky and restrictive for prolonged walking (1). A balaklava (used as a tuque only), mitts and mukluks were worn throughout the experimental session.

Thermistors (YSI, model 44004, Yellow Springs, IL) were affixed in series on the skin and outer surface of each clothing layer (fleece, temperate jacket and arctic parka) at two upper body locations: (a) outer dorsal surface, superior right quadrant in the scapular region at the level of the fossa; (b) outer ventral surface in the lower left quadrant of umbilical region, slightly to the left of the mid saggital line. The posterior thermistor location was 15 cm medial to the shoulder seam and 19 cm inferior to the neck seam of the clothing layer. The anterior location was located 7 cm lateral to the front zipper and 12.5 cm inferior to the base of the seam between the arm and the body of the jacket (armpit seam). The thermistors were glued to the clothing fabric using a wood/fabric glue which was solidified by thread. The presence of a layer of glue to the electrode was not found to substantially affect thermal transmission when compared to thermistors which were pinned but not glued to the clothing. Skin thermistors were positioned at the following locations: right forearm ( $T_{arm}$ ), right finger ( $T_{fin}$ ), right thigh ( $T_{th}$ ) and right toe ( $T_{toe}$ ): the chest ( $T_{ch}$ ) and back ( $T_{ba}$ ). Thermistors were positioned in line with the concomitant clothing thermistors. Rectal temperature ( $T_{re}$ ) was recorded using a YSI, model 401 catheter inserted for a distance of 10-12 cm. Oesophageal temperature ( $T_{oes}$ ) was recorded using a catheter (Baxter, model 400) inserted into the nostrils to a depth equal to one quarter of the subject's height. Temperatures were measured at every five seconds using an automated Data Acquisition Control Unit (Hewlett Packard 3497A) and a Hewlett Packard 9000 PC-31 which measured the resistance of the thermistor and calculated and printed the corresponding temperature. Heart rate (HR) was recorded at 15 second intervals using a heart rate monitor (Polar Electro Technology Sport Tester PE 3000: Nor Am Patient Care Products, Oakville, Ontario). RPC's were obtained using a nine point scale ranging from extremely hot (nine) to extremely cold (one).

Experimental protocol. Prior to each experiment, the subjects were prohibited from participating in any form of physical activity for a period of 24 hrs, ingesting caffeine beverages or alcohol for 12 hrs, solid food for six hours and were required to have at least eight hours of sleep. Prior to the testing session, the subject and individual items of clothing used in the experiment were weighed. The rectal and esophageal catheters were inserted as described above and the thermistors were affixed. The subject then donned the fleece and uninsulated jacket and trousers, mukluks, balaklava and mitts, and then entered the chamber which was set at a temperature of  $-30^{\circ}\text{C}$ . The arctic parka was brought inside the room and hung from the ceiling on a hanger. The subject stood in the chamber beside the treadmill until he felt cold enough to don the parka. At this point, the subject began walking on the treadmill (5% grade) at a pace of 100 steps per min. During the treadmill walk, the subject would doff or don the parka at will to maintain thermal comfort. RPC was recorded every 5 min, when the subject donned or doffed the parka, and at the completion of the experiment. The subject was queried on RPC for total body comfort ( $\text{RPC}_{\text{gen}}$ ) and for each of the skin thermistor locations (except the abdomen). After 60 min of walking, the subject stepped off the treadmill. If at this point the subject was wearing the parka, the experiment was terminated and the subject left the chamber. If not, the subject remained standing in the chamber until he requested to don the arctic parka at which time the experiment was terminated. The subject and clothing were again immediately weighed. Each subject repeated the experimental session once.

## RESULTS

The results of this study indicate that a good degree of reproducibility was obtained. The temperature sites which appeared most reproducible were rectal, thigh, toe, chest and on the front and back temperate clothing. The site of best reproducibility and consistency for donning the jacket occurred at the temperate jacket site while for doffing it was at the skin (chest, back) and fleece temperature sites. The temperature at both the front and back of the temperate jacket when the parka was donned was very reproducible for each individual subject, although the absolute temperatures varied between front and back and among the subjects.

Subjective perception of cold as utilized in this study proved to be very consistent with respect to doffing/donning the parka. The subjects tended to don the parka either after cooling or during exercise when they reported an  $\text{RPC}_{\text{gen}}$  of 3 (cold, intermittent shivering), and to doff the parka when they reported an  $\text{RPC}_{\text{gen}}$  of 7 (hot).  $\text{RPC}_{\text{gen}}$  appears to be more closely related to the trunk skin temperatures than to core temperatures. Doffing/donning of the arctic parka during exercise was not reflected in rectal and oesophageal temperatures. It may be that doffing kept these temperatures from rising and donning from decreasing.

The greatest fluctuations in temperature, as expected, occurred at the temperate jacket sites.  $\text{RPC}_{\text{gen}}$ ,  $\text{RPC}_{\text{back}}$ , and  $\text{RPC}_{\text{chest}}$  were consistent in spite of the progressive lowering of the skin temperatures at which the doffing/donning occurred. Skin temperatures recorded at the back of the trunk were always higher than those at the front of the trunk, suggesting a greater heat loss at this location. Variations in the fit of the clothing leading to differences in insulation are the most likely explanation for this observation. In the two subjects who doffed the parka twice during the walking, the second doffing consistently occurred at lower temperatures for the chest, back, front and back fleece and front temperate jacket sites.

## CONCLUSIONS

From these results, it was concluded that:

- 1) Subjective feelings of coolness and warmth appear to be sufficient for the subject to judge their level of thermal comfort and to maintain thermal balance.
- 2) The main skin temperature sites and associated RPCs most related to doffing and donning are the back and chest.
- 3) Temperature recorded at the level of the fleece appears to be the most reliable indicator signaling doffing/donning of the arctic parka.
- 4) Doffing/donning of the arctic parka is not reflected in core temperatures.
- 5) Changes in overall RPC are not associated with core temperatures.
- 6) RPCs are good indicators of changes in skin temperatures (with the exception of the toe temperature).
- 7) Temperatures recorded within the layers of clothing as utilized in this study provide good indicators of heat loss gradients.
- 8) No relationship was observed between heart rates and donning/doffing of the parka.

## REFERENCES

1. Jetté M., Quenneville J. and Thoden J. 1993, Effects of wearing the new CF cold weather clothing on the performance of selected field tests. Research Report submitted to DREO, Department of National Defence.
2. Penoyer R. 1993, The Alpha-Beta Filter. *The C Users Journal* 11 (7), 73-86.