IECS: SUCCESSFUL IMPLEMENTATION OF THE LAYERING PRINCIPLE

John Frim
Defence and Civil Institute of Environmental Medicine
North York, Ontario, CANADA M3M **3B9**

INTRODUCTION

The layering principle has long been touted as the way to dress for work in the cold. In theory, multiple layers of clothing should allow for adjustment of insulation by the addition or removal of layers as needed to match thermoregulatory requirements under changing weather conditions and/or levels of activity. Failure to adjust insulation could lead to excess sweating and moisture buildup in the clothing with a reduction in effective insulation.

Until recently, achieving a practical layering system has been difficult. This is mainly because many clothing designs rely on the outer layer of fabric as the only protection against the elements of wind, rain, snow, etc.; hence, this layer must always be worn, and it is the underlayers that are added or removed as required. This creates a multi-step undressing/redressing situation, with the result that users may choose not to fuss with the clothing but rather to stay dressed in a less than optimum amount of insulation (perhaps too little, more likely too much).

The Improved Environmental Clothing System (IECS) is a new concept in cold weather clothing for the Canadian Forces (CF) designed to cover the temperature range from +10°C to -40°C. It comprises only three clothing layers, and it is the outer layer that is added or removed to operationally adjust the level of insulation. The key to this system is the incorporation of a water vapour permeable moisture barrier (Goretex®) into both the outer and middle layers. The middle layer is worn at all times, so when the outer layer is removed, as during strenuous activity, the middle layer still provides protection against the elements. The inner layer is worn only during extremely cold weather when the middle layer by itself would be insufficient insulation even during moderate-to-strenuous activity.

The IECS was tested against the current in-service clothing systems in a climatic chamber using both intermittent work **(Work)** and continuous rest **(Rest)** protocols in both high (HI) and low (LO) wind conditions at -10°C and -40°C. Space limitations only permit the -10°C results to be described in detail.

MATERIALS and METHODS

Twelve military subjects participated in this study. Eight were used in each of the two test series (-10°C and -40°C), with four subjects participating in both series.

Three clothing systems were compared in each series: at -10°C the new temperate **(NT)** configuration of IECS was compared to the current temperate **(CT)** and current cold **(CC)** systems; at -40°C the current cold **(CC)** configuration was compared to light parka **(LP)** and heavy parka (HP) versions of IECS, which

differed only in the quantity of insulation. As would be done operationally, the IECS outer parka was donned and doffed for the rest and work phases of the intermittent **Work** protocol, while the parka of the current clothing was simply opened and closed for ventilation.

Physiological measurements included rectal temperature (T_{re}), 12-point skin temperature and heat flux which yielded mean skin temperature (MST) and mean heat flux (MHF), heart rate *(HR),* and nude weight change as a measure of body fluid loss (FLOSS) by sweat. Subjects periodically provided subjective ratings of thermal comfort for whole body, head, hands, feet, arms and legs on a 13 point comfort scale.

Statistical analyses involved a repeated measures analysis of variance (ANOVA repeated, **3** within factors). Attention was focused on the main effect of clothing and on interaction effects in which clothing was a factor; the effects of wind and activity, either singly or in combination, were not considered extensively.

For the -10°C series, all subjects completed 150 min of exposure under all conditions. The final time point data are, therefore, directly comparable and are probably good integrated measures of the performance of the clothing systems under the various test conditions. However, since not all subjects were able to complete the **-40°C** tests, the "final" data from this series represent physiological responses after various times of exposure and may not be directly comparable.

RESULTS

The T_{re} responses over time were quite dependent upon the test conditions. T_{re} was elevated during the **Work** protocol compared with **Rest** irrespective of the clothing worn, and very definite increases in T_{re} (about 0.5°C) were observed during the first **40-min** work phase. During the resting phases of the **Work** protocol, T_{re} dropped by 0.2–0.3°C, only to climb again with commencement of the next activity session.

The data for the **LO** and HI wind conditions were qualitatively similar, the major difference being that T_{re} values at the end of the exposure during HI wind were slightly lower than in the **LO** wind condition. The least difference between wind conditions occurred with ensemble **NT,** suggesting that the new clothing with its Goretex® membrane is very effective at stopping wind.

Perhaps the most important observation is that the **IECS NT** clothing ensemble usually gave responses that were intermediate between **CC** (which may have been too insulative) and **CT** (which may have provided insufficient insulation) during the **Work** protocol. During **Rest,** ensemble **NT** appeared to maintain T_{re} better in the long term than the other two configurations of the current in-service clothing system.

MST followed a rather expected pattern over time. During **Rest,** MST decreased along a smooth exponential-like curve, reaching lower values with HI wind compared with **LO** wind. Also as expected, **skin** temperatures decreased most with

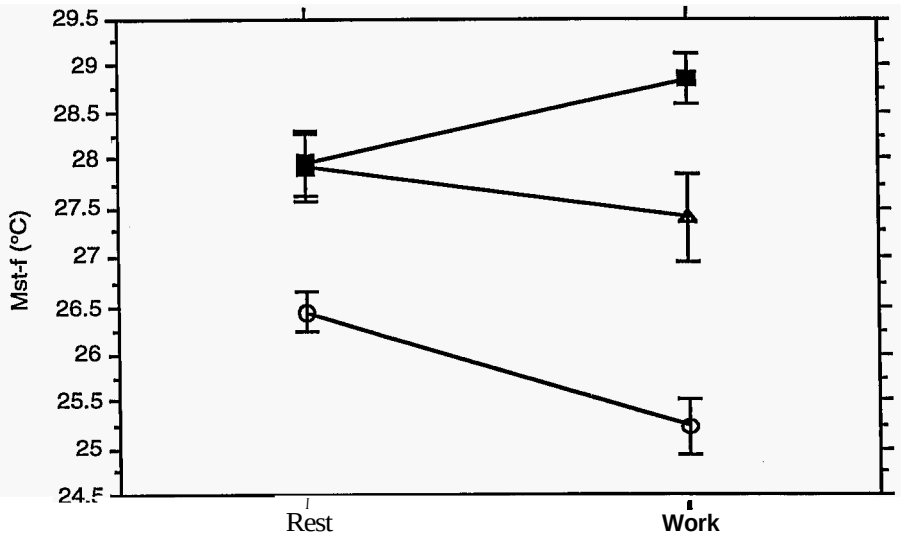

Figure 1. Mean±SEM MST_f at 150 min for clothing ensembles **CT** (circles), **CC** (squares), and **NT** (triangles) during activity protocols **Work** and **Rest** averaged over **HI** and **LO** wind conditions.

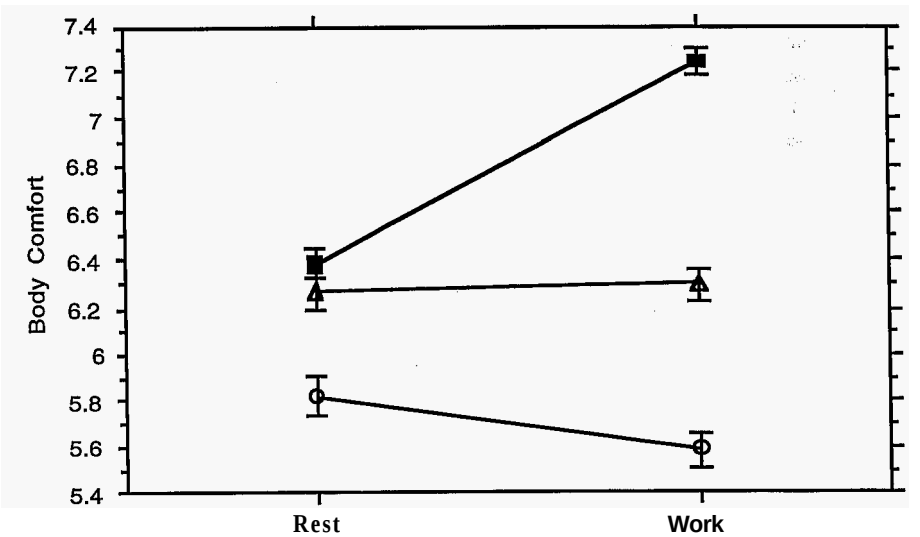

Figure 2. Whole body comfort with the three clothing ensembles (symbols as in Fig 1) under the two activity conditions (averaged over wind and time).

ensemble **CT.** During **Work,** a similar overall cooling trend for MST was observed, but with superimposed undulations which followed the work/rest intervals of the **Work** protocol. Keeping the **CC** parka on (albeit open) definitely kept skin temperatures warmer (perhaps too warm) than donning and doffing the **NT** parka. However, since all subjects tolerated 150 min of the test, ensemble **NT** was probably warm enough.

The final mean skin temperature (MST_f) clothing by activity interaction plot ($p<0.01$) is shown in Figure **1.** Ensemble **CT** was clearly unable to maintain warm skin temperatures, especially during **Work.** Whereas there was no difference between ensembles **CC** and **NT** during **Rest,** there was a clear difference during **Work. As** to which response is more desirable, the FLOSS data indicated 58% more sweat loss during **Work** with ensemble **CC** compared to ensemble **NT.**

In general, thermal comfort declined over time. Overall mean scores at 150 min were approximately 6.8 for the head, 6.0 for the whole body, **5.4** for the hands, and 5.3 for the feet. The influence of activity could clearly be seen in that during **Rest** the declines were quite smooth whereas during **Work** the ratings undulated in response to the cyclic activity. In the majority of cases, the **NT** ensemble comfort scores were between those of ensembles **CC** and **CT.**

Figure **2** shows the clothing by activity interaction for whole body comfort. For ensemble **NT** the whole body rating remained quite steady between **Work** and **Rest,** whereas **CC** showed too much warmth during **Work.** This is consistent with the MST and FLOSS data presented previously.

Most subjects were not able to tolerate 150 min at -40°C, especially not with HI wind. It is noteworthy, however, that the longest durations were obtained with the **IECS.** Surprisingly, little difference was noted between the two levels of insulation.

CONCLUSIONS

As a general summary of the thermal comfort results, subjects preferred the IECS over the current clothing systems. It allowed simple adjustments to the insulation levels to accommodate various activity levels, and its insensitivity to wind, probably due to the Goretex® membrane, demonstrates a superior garment system.

Based on physical, physiological and subjective data, the IECS clothing system performed "better" than the current in-service clothing. Follow-on field trials and in-service use have confirmed the benefits and user acceptance of this new clothing system. Employing modem clothing materials, the IECS finally brings the layering principle into practice.