Heated Garments for Warfighter Operations in Subarctic Conditions

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Introduction

Uniforms are designed to aid the wearer and improve their performance, often including unique performance features. For warfighters, the goal is no different. Hundreds of hours of work go into improving and redesigning **warfighter uniforms** to ensure these suits are maximally efficient. Warfighters stationed in extreme cold may routinely experience temperatures of -60˚ C or lower. In these extreme conditions, it is crucial to provide appropriate thermal insulation in order to prevent hypothermia, decline in performance, and maintain stable core temperatures. The greatest risk regarding warfighter uniforms in extreme cold is a decrease in peripheral temperature, such as fingers and toes, which results in decreased manual dexterity and increased thermal discomfort (Castellani et al., 2017; Jones et al., 2007). This is especially concerning for **aircraft pilots**, who need to be able to make precise movements to perform their duties. Multilayer fabric ensembles that are designed to withstand this extreme cold are in use; however, they are often bulky, resulting in limited mobility and dexterity for the wearer. For those who require mobility for their duties, these ensembles are not ideal. In an attempt to maintain thermoregulation in extreme **subzero conditions** without added bulk, direct personal warming systems may be integrated into base layer clothing. The purpose of this study is to evaluate the efficacy of a **proprietary heated base layer** in subzero conditions.

Methods

Sample
- Three cold weather ensembles
  - Light, Intermediate, and Cold (see Figures 6-8)
- In addition, a proprietary base layer was added under each with four levels of heat
  - Zero, Low, Medium, and High
- Wattage varied by region (hands, back, chest, and feet; see Figure 4)

Procedure
- 35 Zone ANDI Dynamic Sweating Thermal Manikin (see Figure 9)
- Dynamic heat flux sensors with active cooling system
  - Ability to measure heat loss AND heat gain
- Modified ASTM F1291 method
  - Nonisothermal conditions (20°C/50% RH)

Measurements
- Total thermal resistance (Rt) (ºC/m^2/W)
- Total thermal insulation (Clo; see Figure 5)

Results

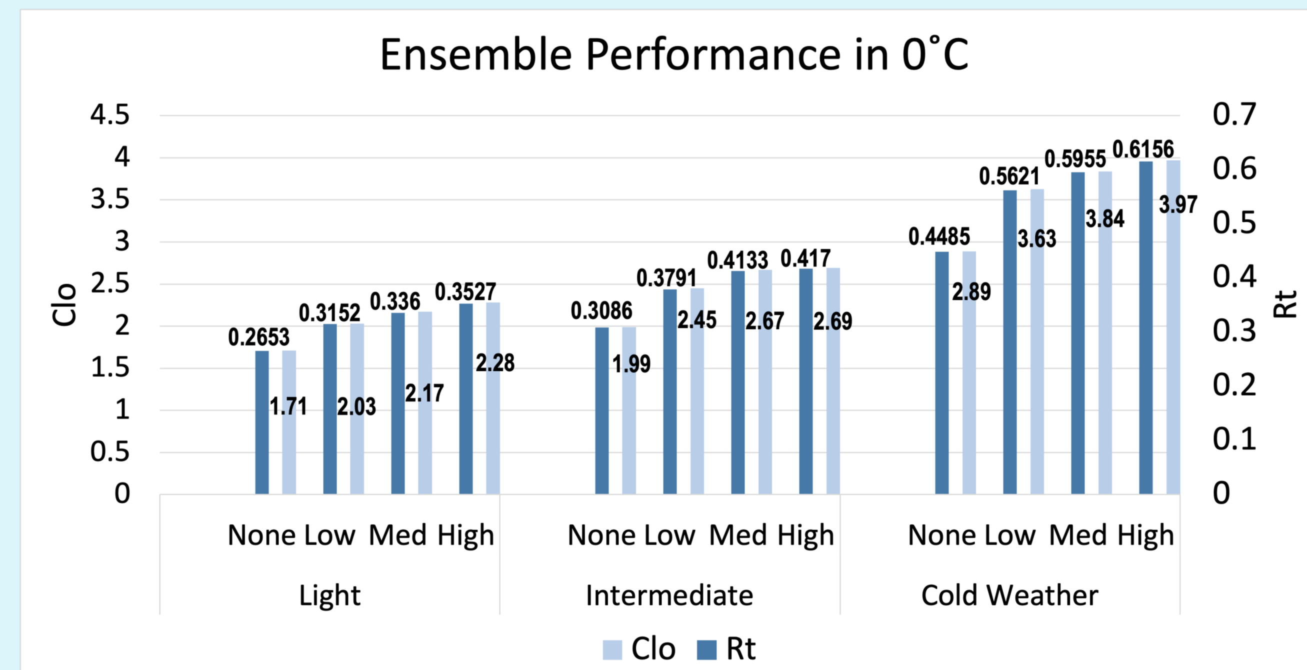

Figure 1. Average total thermal resistance (Rt) and total thermal insulation (Clo) of the low, intermediate, and cold weather ensemble at each power level in 0˚C.

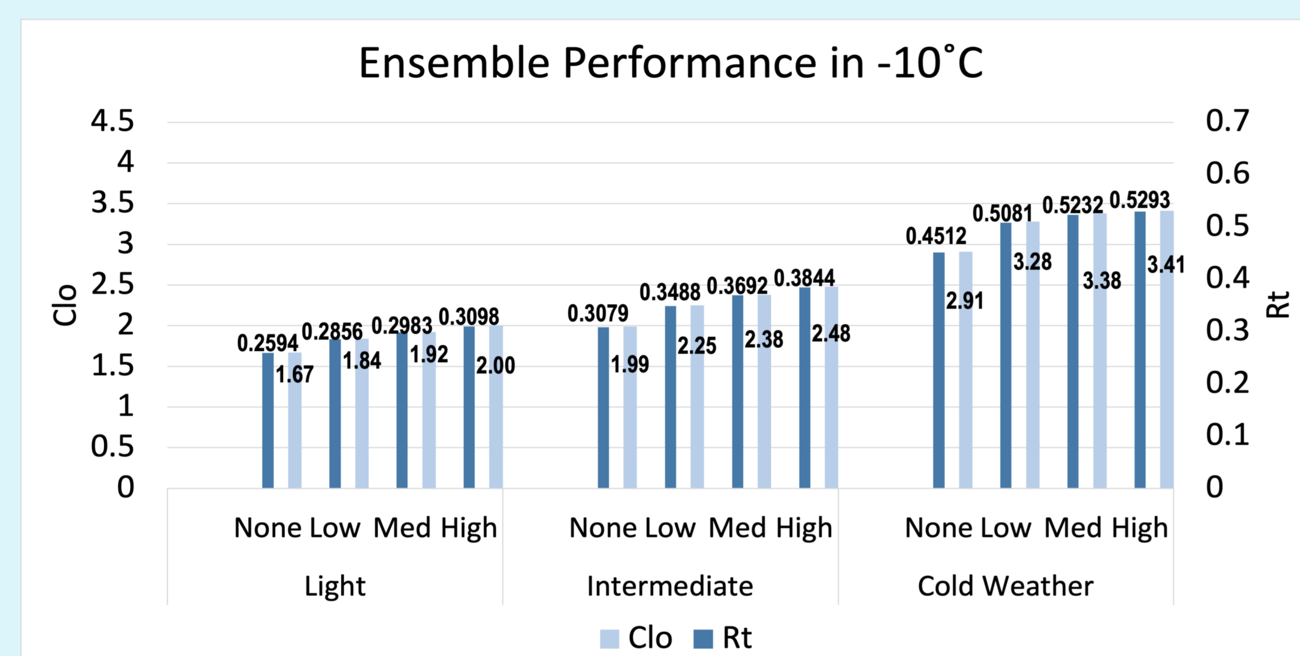

Figure 2. Average total thermal resistance (Rt) and total thermal insulation (Clo) of the low, intermediate, and cold weather ensemble at each power level in -10˚C.

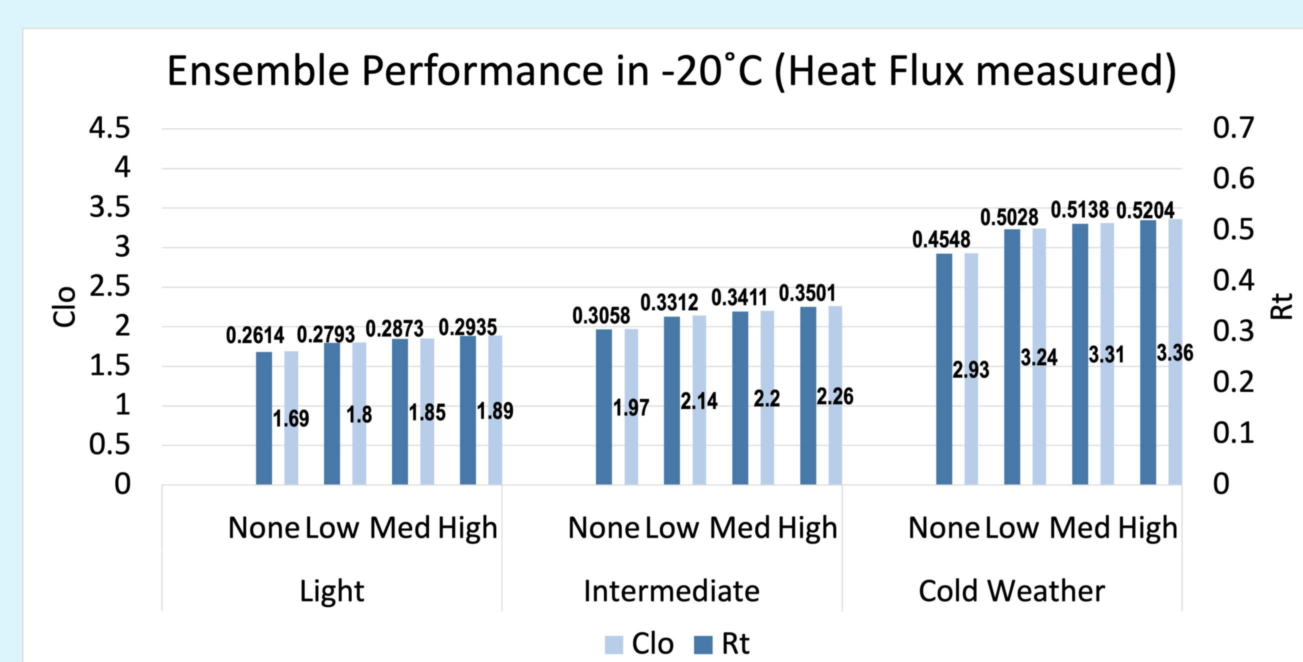

Figure 3. Average total thermal resistance (Rt) and total thermal insulation (Clo) of the low, intermediate, and cold weather ensemble at each power level in -20˚C.

Heat Level	Wattage
Zero	0 W
Low	7.5 W
Medium	10 W
High	12.5 W

Figure 4. Corresponding wattage to each power level of heated ensembles

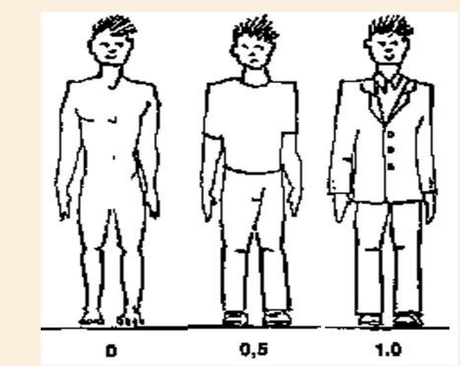

Figure 5. Clo unit visual demonstration

Discussion & Conclusion

After completing this research, we have come to two main conclusions. First and foremost, the proprietary heated base layer is able to successfully warm the body in all three temperature conditions, regardless of the ensemble it is paired with. The **heated component** was also able to increase the total thermal resistance and the total thermal insulation in each temperature condition. However, it is important to note that as the conditions became colder, the power levels of the suit became less effective, in that it wasn't able to increase the total thermal resistance and total thermal insulation by as large of a margin. Because this research only tested the suit from 0˚C to -20˚C, further research is needed to determine if this ensemble would be effective in subarctic locations where temperatures reach -60˚C.

Figure 6. Light ensemble

Figure 7. Intermediate ensemble

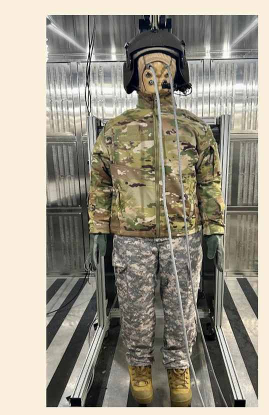

Figure 8. Cold weather ensemble

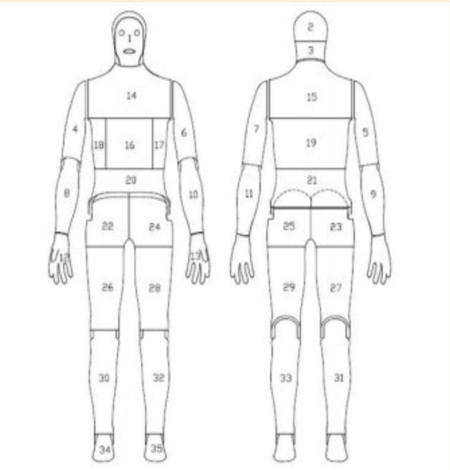

Figure 9. Labeled heated regions of the ANDI Manikin

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