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Assessment of Hypothermia Blankets Using an Advanced Thermal Manikin

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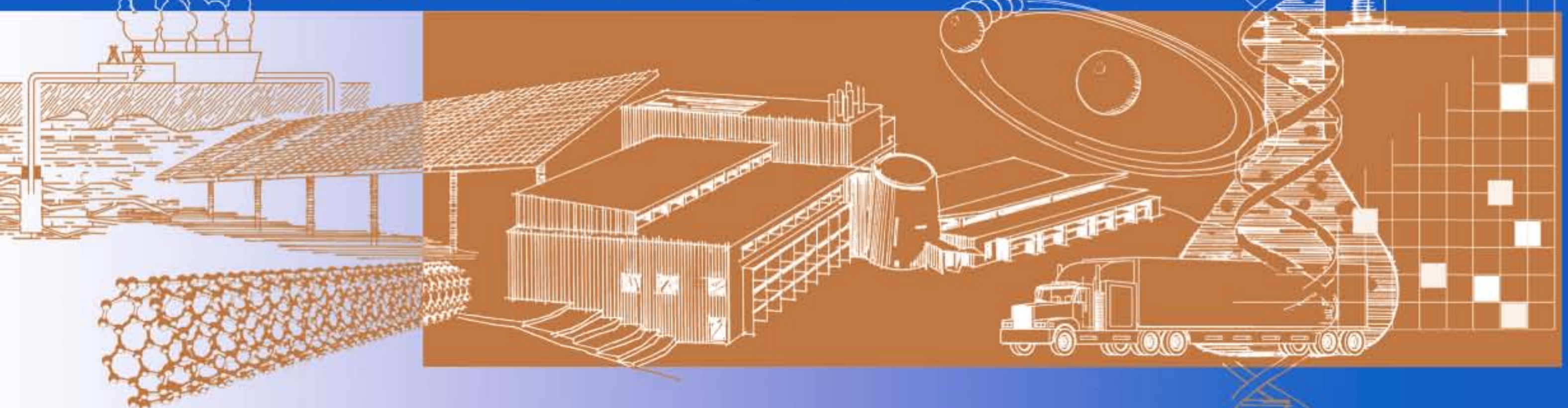

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Assessment of Hypothermia Blankets Using an Advanced Thermal Manikin

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INTRODUCTION

The U.S. Army Aeromedical Research Laboratory (USAARL) and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) used NREL's thermal manikin, controlled by a human thermal physiological model, to assess various hypothermia blankets. These blankets are important during medical transport because environmental conditions, coupled with a patient's traumatic injury, can often lead to physiological thermal imbalance. High wind and low air temperatures during a medical evacuation can lead to excessive heat loss from the patient, resulting in hypothermia. This condition can complicate the treatment of the patient upon arrival at the hospital.

NREL's thermal comfort tools consist of the thermal comfort manikin (ADAM, for ADvanced Automotive Manikin), a physiological model, and a psychological model linked together to assess comfort in a transient, nonhomogeneous environment (1, 2). In the integrated human thermal comfort system, ADAM is controlled by a finite-element physiological model of the human body.

The thermal manikin is a surface sensor that measures the rate of heat loss at 120 independently controlled zones. The skin heat transfer rates are sent to the physiological model, which computes the skin and internal temperature distribution and surface sweat rates. This information is then sent back to the manikin, which generates the prescribed skin temperatures, surface sweat rates, and breathing rates. As the model steps forward in time, this loop provides a transient measurement tool. The psychological comfort model uses temperature data from the physiological model to predict local and global thermal comfort as a function of local skin and core temperatures and their rates of change.

METHODS

Testing was conducted in NREL's Manikin Environmental Chamber in Golden, Colorado. The test conditions were 15ºC air temperature and 50% to 60% relative humidity. Three portable fans provided 7 mph airflow over the manikin.

Four hypothermia blanket configurations were tested in conjunction with a stretcher: (1) wool army blanket (heat retention), (2) electric heating blanket, (3) radiant heating blanket, and (4) chemical heating blanket. The Army blanket was a standard-issue brown rectangular blanket. The electric heating blanket consisted of a lightweight inner wrap and an outer shell blanket containing heating elements. The radiant heating blanket used resistive carbon fiber technology with a microprocessor-controlled temperature regulation system. The radiant blanket contained five woven carbon fiber warming panels, each measuring 9 by 14 inches, designed to distribute heat evenly from the shoulders to below the feet. The chemical heating blanket system consisted of a sheet next to the patient, a thin blanket containing the chemical, and an outer radiation shield. The sheet was a regular bed sheet placed between the manikin and the chemical blanket to protect the skin from excessive temperature. The chemical blanket layer had six pouches measuring 7 by 10 inches containing the chemical material that generated heat when exposed to air. The outer shield was 88 by 93 inches and had a reflective inner surface to reflect body heat back to the patient. Thermocouples were secured to the chemical blanket layer to assess potential hot spots.

The manikin was placed on an actual medical evacuation stretcher made of a mesh material and a frame that allowed air flow under the patient. The manikin was unclothed under the thermal blankets, and the manikin's uncovered head extended beyond the edge of the blanket. Figure 1 shows ADAM testing the wool Army blanket. Figure 2 shows the electric and radiant heating blankets, and Figure 3 shows the chemical blanket.

Figure 1. Test of a Wool Army Blanket Using the Thermal Manikin

Figure 2. Electric and Radiant Heating Blankets

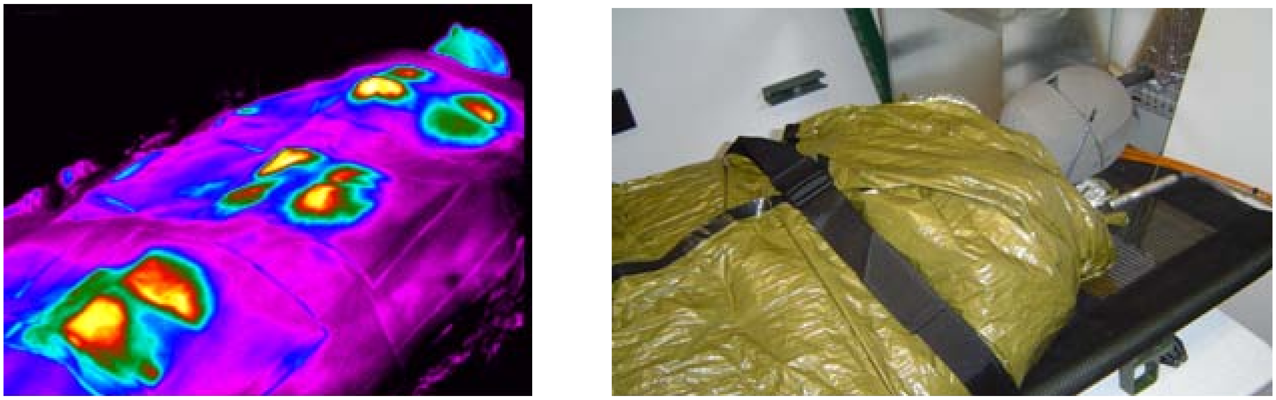

Figure 3. IR Image of the Chemical Blanket and Photo of the Outer Radiation Shield

During the first part of the test, the steady-state heat loss from the manikin was measured at constant skin temperatures of 34ºC and 40ºC for each blanket configuration. We found that a skin temperature of 34ºC was not hot enough for active blanket configurations. When the zone skin temperature exceeded 34ºC, the heater turned off and there was no longer active control for that zone. Therefore, we had to increase to a skin control temperature of 40ºC for the steady-state tests to increase the number of segments with active control.

Immediately after the steady-state constant skin temperature test, the manikin was controlled with the physiological model, and the metabolic rate was set at 95 W. The test was run until a steady-state core temperature was attained. Key outputs of skin and core temperature were compared for each blanket configuration. The core temperature was defined as a volume average temperature of the brain. This was useful for a run-to-run comparison, but it should not be used to define the onset of hypothermia. A different definition of core temperature would produce a different result. The average skin temperature was defined as an average of 16 skin temperatures distributed around the body.

RESULTS

The constant skin temperature steady-state results are shown in Figure 4. When wrapped in a wool blanket, the manikin measured a 205.5 W/m^2 heat loss. The test of the electric blanket resulted in a higher heat loss, and that of the radiant blanket produced a lower heat loss. The heat loss result for the chemical blanket was significantly lower, at 79.5 W/m^2. This finding was mainly due to the outer radiation shield of the chemical heating blanket system. Tests performed without having the radiation shield well wrapped and without the radiation shield altogether yielded higher heat losses.

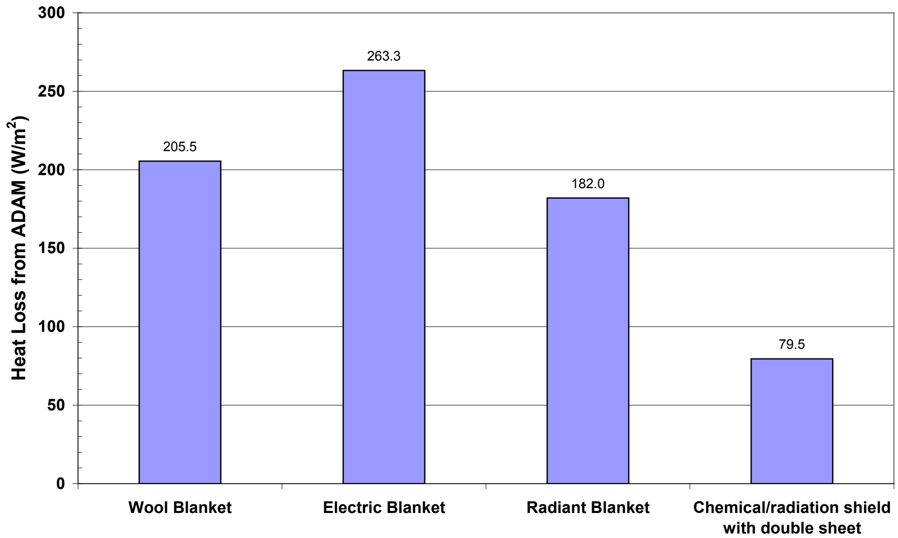

Figure 4. Steady-State Heat Loss with 40°C Skin Temperature

Controlling the manikin with the physiological model yielded results that were similar to those of the constant skin temperature tests. Figure 5 shows that the wool blanket produced a manikin core temperature of 33.9°C. The test of the electric blanket resulted in the lowest core temperature, and that of the chemical blanket produced the highest core temperature of 35.4°C.

The skin temperatures were consistent with the core temperature results, except for the electric blanket. In that case, the average skin temperature was warmer than the wool blanket, while the core temperature was cooler. The chest and leg temperatures were warmer, but there was greater heat loss and lower skin temperatures on the manikin's sides and back. The average skin temperature calculation was constrained to 16 points and missed these cool spots. The manikin with physiological model control responded to the environment with higher fidelity and measured a lower core temperature. The chemical blanket test resulted in the warmest skin temperatures, although this blanket produced hot spots up to 70ºC on the surface of the blanket.

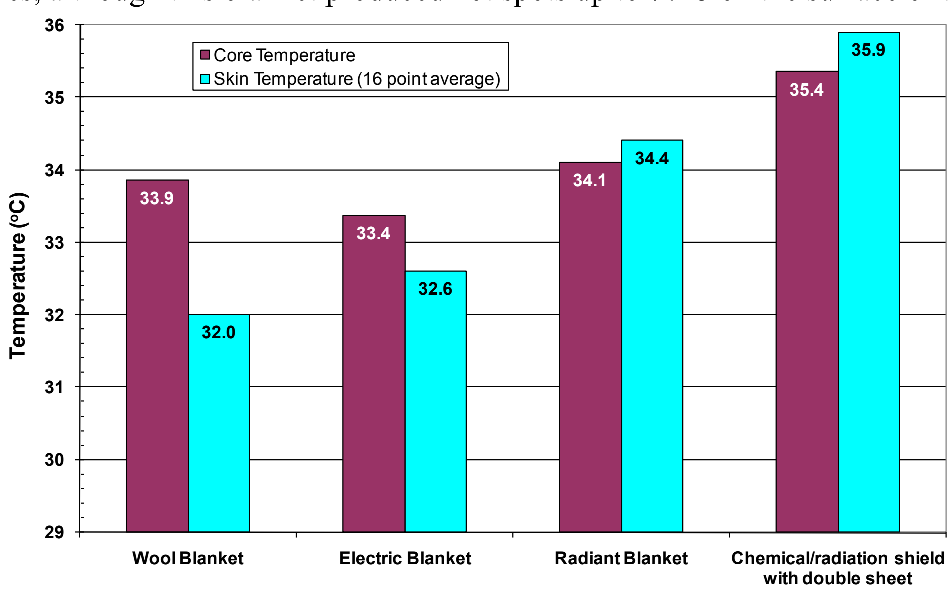

Figure 5. Average Skin and Core Temperatures during Physiological Model Control

For the wool, electric, and radiant blanket tests, placing a wool blanket between the manikin and stretcher significantly reduced heat loss (Figure 6). For the wool blanket case, placing a wool blanket under the manikin resulted in a 30% reduction in heat loss, to 144.4 W/m^2. This was a better result than those for the regular electric and radiant blankets. The chemical blanket was not impacted by placing the wool blanket underneath it because it was already well wrapped and insulated because of the radiation shield. Placing a radiation shield around a wool blanket with wool underneath resulted in an additional 30% drop in heat loss, from 144.4 to 101.8 W/m^2.

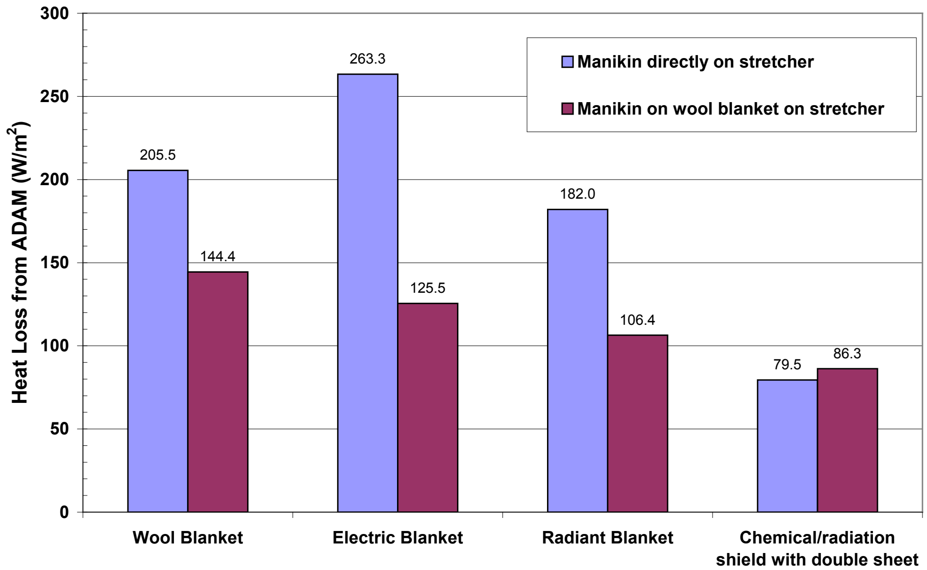

Figure 6. Impact on Heat Loss of Placing a Wool Blanket under the Manikin

CONCLUSIONS

The thermal manikin was successfully used to assess thermal blankets. The chemical blanket showed the best thermal performance, specifically, the lowest heat loss and the highest skin and core temperatures. Care providers should not place a chemical heating blanket directly on the patient's skin, however. The electric blanket showed the highest heat loss and coolest core temperature. Placing a wool blanket between the manikin and the stretcher significantly reduced heat loss when the wool, electric, and radiant blankets were used. Wrapping a radiation shield around a conventional wool blanket and using a wool blanket underneath the patient further reduced heat loss.

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14. ABSTRACT *(Maximum 200 Words)*
A thermal manikin developed at NREL was used to assess several thermal blankets intended to help treat U.S. Army personnel suffering from hypothermia. The chemical blanket showed the best thermal performance, specifically, the lowest heat loss and the highest skin and core temperatures. Care providers should not place a chemical heating blanket directly on a patient's skin, however. The electric blanket showed the highest heat loss and coolest core temperature. Placing a wool blanket between the manikin and the stretcher significantly reduced heat loss when the wool, electric, and radiant blankets were used. Wrapping a radiation shield around a conventional wool blanket and using a wool blanket underneath the patient further reduced heat loss.

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