

**ABILITY OF A PASSIVE MICROCLIMATE COOLING VEST TO REDUCE THERMAL STRAIN AND INCREASE TOLERANCE TIME TO WORK IN THE HEAT**

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**INTRODUCTION.** The U.S. Navy Clothing and Textile Research Facility (NCTRF) has previously conducted laboratory evaluations to compare the effectiveness of various types of commercially available, microclimate cooling systems in reducing heat strain (1, 2). The systems tested have included air vests, circulating liquid vests, and frozen gel or ice ("passive" cooling) vests. Based on its ability to reduce thermal strain as well as its potential feasibility for shipboard use, one of the "passive" cooling systems was recommended for U.S. Navy shipboard use. The system is easy to use, is not subject to mechanical failure and requires very little maintenance. Compared with the other commercially available microclimate cooling systems, the system is relatively lightweight (5.1 kg), less bulky and low cost. Subsequently, the Navy has procured several thousand cooling systems and outfitted a number of ships. The selected system consists of an insulated, fire-retardant cotton canvas vest with six pockets (three on the front, three on the back) which each hold a frozen gel strip against the torso. The total weight of the gel strips is 4.6 kg; the total weight of the cooling system is 5.1 kg. Further laboratory testing of the selected system has been conducted by NCTRF (3), and shipboard testing has been conducted by the U.S. Naval Health Research Center (NHRC) (4). Currently both Facilities are collaborating by conducting a series of similar but separate data collections at each laboratory which will result in the development of recommended safe tolerance times when the cooling system is used by U.S. Navy shipboard personnel. The present paper describes the core temperature, skin temperatures, heart rate, sweating rate and tolerance time responses measured on 14 subjects at the NCTRF laboratory. The second paper describes results on additional cardiovascular variables that were measured on eight subjects during the data collection at the NHRC laboratory.

**METHODS.** Fourteen male subjects (average age, 21 yr; height, 179 cm; weight, 80.2 kg) underwent 8 days of heat acclimation followed by six heat stress tests. The heat stress tests were conducted in three different environments: environment A = 44°C dry bulb (db) temperature, 46°C black globe (bg) temperature and 49% relative humidity (rh); environment B = 51°C db, 53°C bg and 33% rh; environment C = 57°C db, 59°C bg and 25% rh. In each environment, each subject performed two heat stress tests: once while using the cooling vest and once without (control test). During each test, subjects attempted to complete a 6-hour exposure while alternating 20 minutes of treadmill exercise (at a speed of 1.1 m/s on a 3% grade) with 40 minutes of seated rest. This resulted in a time-weighted metabolic rate of 208 watts, which corresponds to the third in a series of six work rates typical of normal shipboard operations. Subjects wore the U.S. Navy utility work uniform (thermal insulation = 1.1 clo; water vapor permeability ( $i_m$ ) index = 0.6). When the cooling vest was used, it was worn over the T-shirt and work shirt. Physiological measurements included rectal temperature; chest, upper arm, calf and thigh skin temperatures; heart rate; and total body sweating rate. Termination criteria for each test included rectal temperature of 39.5°C; heart rate >180 bpm for 5 minutes during exercise, or >160 bpm for 5 minutes during rest; or voluntary withdrawal due to heat strain symptoms, such as nausea, faintness, etc. Two-way repeated measures analyses of variance (vest versus control / time) were conducted on the data from each of the three environments. Because of subject attrition during the control tests, statistical comparisons were made up to the following times: 200 minutes in environment A, 80 minutes in environment B, and 60 minutes in environment C.

**RESULTS.** In environment A, five of the 14 subjects were able to complete the 6-hour heat exposure during the control test. When the cooling vest was used, all 14 subjects completed the exposure. In environments B and C, use of the cooling vest more than doubled tolerance time compared with the control tests. The increase in tolerance time due to the vest averaged approximately 3 hours in environment B, and over 1.5 hours in environment C. In all three environments, use of the vest resulted in significant reductions in rectal temperature, chest temperature, heart rate and sweating rate compared with the control tests ( $p < 0.05$ ). Upper arm, calf and thigh skin temperatures were not significantly different between the cooling vest and the control tests ( $p > 0.05$ ). The reduction in rectal temperature when the vest was used averaged  $0.4^{\circ}\text{C}$  in environment A (after 200 minutes of heat exposure),  $0.7^{\circ}\text{C}$  in B (after 80 minutes of heat exposure), and  $0.8^{\circ}\text{C}$  in C (after 60 minutes of heat exposure). The reduction in chest temperature averaged  $8^{\circ}\text{C}$  in environment A (at 200 minutes),  $8^{\circ}\text{C}$  in environment B (at 80 minutes), and  $5^{\circ}\text{C}$  in environment C (at 60 minutes). Heart rate was reduced by 18, 25 and 20 bpm in environments A (at 200 minutes), B (at 80 minutes) and C (at 60 minutes), respectively. Use of the cooling vest reduced total body sweating rate by 49%, 45% and 38% in environments A, B and C, respectively.

**CONCLUSIONS.** Use of the passive cooling vest significantly reduced thermal strain, as evidenced by reduced rectal temperature, chest temperature, heart rate and sweating rate. When the cooling vest was used by subjects wearing a standard work uniform and performing light exercise in extreme hot environments, work time was more than doubled compared with control tests. Use of the vest reduced total body sweating rate by an average of over 40%. Drinking water requirements, therefore, would also be lowered.

#### REFERENCES

1. Pimental, N. A., B. A. Avellini and C. R. Janik. 1988, Microclimate cooling systems: a laboratory evaluation of two commercial systems. Natick, MA: Navy Clothing and Textile Research Facility; Technical Report No. 164.
2. Pimental, N. A. and B. A. Avellini. 1989, Effectiveness of three portable cooling systems in reducing heat stress. Natick, MA: Navy Clothing and Textile Research Facility; Technical Report No. NCTRF 176.
3. Pimental, N. A. and B. A. Avellini. 1992, Effectiveness of a selected microclimate cooling system in increasing tolerance time to work in the heat. Natick, MA: Navy Clothing and Textile Research Facility; Technical Report No. NCTRF 181.
4. Banta, G. R. and D. E. Braun. 1990, Heat strain during at-sea helicopter operations in a high heat environment and the effect of passive microclimate cooling. San Diego, CA: Naval Health Research Center; Technical Report 90-30.