

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<sub>m</sub>**) 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°C** in environment A (after 200 minutes of heat exposure), **0.7°C** in B (after 80 minutes of heat exposure), and **0.8°C** in **C** (after 60 minutes of heat exposure). **The** reduction in chest temperature averaged **8°C** in environment A (at 200 minutes), **8°C** in environment B (at 80 minutes), and **5°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

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