Effects of a New Cooling Technology on Physical Performance in US Air Force Military Personnel

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Abstract

Heat-related illness is a critical factor for military personnel operating in hyperthermic environments. Heat illness can alter cognitive and physical performance during sustained operations missions. Therefore, the primary purpose of this investigation was to determine the effects of a novel cooling shirt on core body temperature in highly trained US Air Force personnel.

Methods

Twelve trained (at least 80th percentile for aerobic fitness according to the American College of Sports Medicine, at least 90% on the US Air Force fitness test), male Air Force participants (mean values: age, 25 ± 2.8 years; height, 178 ± 7.9cm; body weight 78 ± 9.6kg; maximal oxygen uptake, 57 ± 1.9mL/kg/ min; and body fat, 10% ± 0.03%) completed this study. Subjects performed a 70-minute weighted treadmill walking test and 10-minute, 22.7kg sandbag shuttle test under two conditions: (1) "loaded" (shirt with cooling inserts) and (2) "unloaded" (shirt with no cooling inserts).

Results

Core body temperature, exercise heart rate, capillary blood lactate, and ratings of perceived exertion were recorded. Core body temperature was lower ($p = .001$) during the 70-minute treadmill walking test in the loaded condition. Peak core temperature during the 70-minute walking test was also significantly lower ($p = .038$) in the loaded condition. Conclusion: This lightweight (471g), passive cooling technology offers multiple hours of sustained cooling and reduced core and peak body temperature during a 70-minute, 22.7kg weighted-vest walking test.

Introduction

Special Operations Forces (SOF) are exposed to austere environments during training and sustained operations (SUSOPS) missions. Operations in hyperthermic environments may impair physical performance and even result in death. Impaired physical performance can limit the ability of SOF to adequately sustain and satisfactorily complete specified duties required during SUSOPS missions.Humans cool themselves in hyperthermic environments by increasing blood flow to the periphery to shed heat through radiation at rest. However, during physically demanding tasks, blood flow to the periphery is further increased to release heat through evaporation, and by convection, if air movement is present. Prolonged work (e.g., in excess of 8 hours) in hyperthermic environments typically results in dehydration from excessive sweat and associated sodium chloride losses. Ultimately, the competition between demands for blood flow to working skeletal muscle and to regulate body temperature, as well as dehydration from sweat loss, result in physical and mental exhaustion as well as thermal injury. The most serious form of thermal injury, heat stroke, results from the body's inability to dissipate heat, which induces an excessive rise in core body temperature. A high core body temperature, defined as greater than 41°C, may result in mental confusion, dry skin, delirium, convulsions, and unconsciousness. The estimated death rate for subjects suffering from heat stroke is 20%. Precautionary measures included in a military training program include acclimatization procedures, and ingestion of fluids before and during vigorous physical activity. Failure to train troops correctly or use the appropriate cooling devices in hot, humid environments may result in mission mishaps. For example, when heat accumulation exceeds removal, brain temperatures may exceed 40°C, resulting in central fatigue, and impairing the ability of SOF to sustain normal cognitive function and physical work intensity. Brain temperature is a critical factor affecting motor skill ability during exercise in hyperthermic conditions, during which there is an estimated 7% ± 2% greater heat production in the brain. Based on these results, the mean brain temperature is estimated to be 0.2°C higher than core body temperature during sustained aerobic exercise in either normal or hot, humid conditions, ultimately impairing cognitive ability. Additionally, when a troop member suffers from fatigue because of a physical or cognitive heat-related illness, an estimated four members of the squadron are needed to carry him/her any distance.

Therefore, the prevention of heat illness among military troop members seems prudent in ameliorating battlefield mishaps and improving field performance. Cooling devices have been introduced to help reduce the occurrence of heat illness. Various cooling devices are often applied to the head and neck regions based on the concept that brain temperature can be controlled through active cooling of that region. Local cooling of the carotid arteries during high-intensity exercise has been found to attenuate increasing brain temperatures, reduce core temperatures, and improve perceptions of physical efforts.

Active cooling of the neck enhances the vasodilation response of the carotid arteries, effectively cooling the cerebral vessels. However, these cooling devices connected to a core-cooling vest are not strategically placed over the right or left common carotid artery. Neck-cooling collars, cooling bandanas, cooling vests, and clothing containing cooling microgels may contribute to enhanced work capacity. However, these cooling devices may be bulky and frequently require ice or gels, which are impractical for many troops who must carry all of their gear for long distances during SUSOPS. Traditional cooling treatments (such as immediate hydration or placing overheated individuals in a cool room) remove troops suffering from heat illness from their relevant military duties, which places greater physical demands on other troop members. Those may not be options in some circumstances. Clearly, there is a need for effective, lightweight, portable methods of cooling that do not require a power source during SUSOPS. The moisture wicking shirt with Arctic Ease® cryotherapy inserts (Gawi Healthcare, http://arcticeasewrap .com) could provide sustained cooling effects, would not necessarily add weight to the backpack, would not require maintenance, and could be used by a large number of SOF or military personnel working in hot, humid environments. Because heat-related illness is a critical factor for military personnel operating in highheat environments and can alter judgment and physical performance, this study was conducted to determine the effects of this novel cooling shirt on core body temperature during high--intensity physical activity in a laboratory setting.

Materials and Methods

This cooling garment is a custom-designed shirt containing 44% Pima cotton micro model, 8% polyester, and 4% Spandex. Pockets of the same material were created to fully encapsulate the lightweight cryotherapy pad. The cooling medium is flame resistant to 815°C, adding to the garment's capabilities of meeting Air Force requirements for flame resistance. The shirt weighs 203g, for a total of 471g with the cooling insert. Subjects Twelve healthy, active-duty, male military members between the ages of 19 and 30 years were recruited for participation in this study (mean values: age, 25.42 ± 2.84 years; height, 178.9 ± 7.92cm; weight, 78.25 ± 9.61kg; maximal oxygen uptake, 57.96 ± 1.96 mL/ kg/min; body fat, 10% ± 0.03%). Each provided written informed consent in accordance with the Air Force Research Laboratory Institutional Review Board. Eligibility for study participation was determined during a physical screening evaluation on the first visit. Body composition was assessed using a three-site skinfold measurement of the chest, abdomen, and thigh. Aerobic fitness was assessed using a single-stage submaximal treadmill walking test.16 Subjects ranking in the top 80th percentile for aerobic fitness and top 60th percentile for body composition, according to American College of Sports Medicine normative data,17 were eligible for study entrance Experimental Protocol Subjects meeting the inclusion criteria returned to the laboratory for four additional testing sessions, each separated by a 72-hour recovery period. For each testing session, subjects wore a novel cooling garment and military Airmen Battle Uniform (ABU). The cooling garment consisted of a custom-designed, form-fitting shirt made from moisture-wicking fabric with a pocket over the chest and back for the placement of cooling cryotherapy pads. Two hours prior to each testing session, subjects were asked to swallow a core body temperature pill (CorTemp Core Body Temperature Sensor; HQ Inc., http://www.hqinc.net) with a glass of tepid water. Subjects returned to the laboratory 72 hours after each test to confirm that the core body temperature sensor was properly expelled from the digestive tract. During the first and second testing sessions, subjects completed a 70-minute, 22.7kg-weighted treadmill walking test. One session was performed with the cooling inserts ("loaded") and one session was completed without the cooling inserts ("unloaded"). Treatment order was counterbalanced by the subjects to minimize order effect. First, subjects were fitted with a 22.7kg weighted vest (Better Fitness, Inc., https://www.betterfitnessproducts. com) and heart rate monitor with chest strap (POLAR® Heart Rate Monitor System; HQ Inc.). Next, subjects performed a 5-minute aerobic warm-up on the treadmill (Woodway USA, http://www.woodway.com) at 0% grade. During the warm-up period, subjects self-selected a comfortable walking speed. After the 5-minute warmup, treadmill grade was increased to 2%. Subjects then walked continuously for 60 minutes at the pace selected during the warm-up. Finally, subjects performed a 5-minute recovery walk at a self-selected treadmill speed. Exercise heart rate and core body temperature were captured continuously using the CorTemp Data Recorder (HQ Inc.). Perceived exertion was assessed every 3 minutes using the 6 (very, very light) to 20 (very, very hard) graded scale.18 Capillary blood lactate level was assessed with the Lactate Pro Blood Lactate Test Meter (YSI, Inc.) within 3 minutes of the recovery period. During the third and fourth testing sessions, subjects completed a 10-minute lift-and-carry shuttle test wearing a 22.7kg weighted vest. Again, the subjects counterbalanced loaded and unloaded sessions.

Subjects were instructed to lift a 22kg sandbag from the ground, carry it 10m, and place it on a platform at a height of 1.45m. Subjects then returned the sandbag to the floor at the start line, signifying one complete shuttle. Subjects completed as many shuttles as possible in 10 minutes while wearing a 22.7kg weighted vest and POLAR heart rate monitor. Exercise heart rate and core body temperature were captured continuously using the CorTemp Data Recorder. Perceived exertion was assessed every 2 minutes using the 6 (very, very light) to 20 (very, very hard) graded scale.18 Capillary blood lactate level was assessed with the Lactate Pro Blood Lactate Test Meter within 3 minutes of completing the shuttle test.

Statistical Analysis

Analysis was performed using SPSS software for Windows (version 19; IBM, https://www.ibm.com). Means and standard deviations were calculated. Differences were assessed using a two-factor (insert time), repeated measures analysis of variance. When a significant F ratio was obtained, paired t tests were used to isolate differences among treatment means. Pearson correlations were used to evaluate associations among variables. An α of $p \leq .05$ was considered statistically significant.

Results

This study examined the effects of a cooling shirt on core body temperature during physical activity with a 22.7kg weighted vest with the subject wearing an ABU. Subjects completed two rigorous physical tests with and without the Arctic Ease cooling pad inserted into the lightweight shirt with pockets located on the front, back, and midaxillary: (1) a 70-minute treadmill, weighted-vest walking test where only core body temperature was measured; and a sandbag shuttle test that required participants to carry a 22kg sandbag while wearing a 22.7kg weighted vest for 10 minutes or until reaching volitional fatigue. The two physiological tests chosen for this study simulated "real-time" field performance tests typically required of SOF during training and in the battlefield. SOF may be exposed to harsh environmental conditions such as hot, humid austere climates.The cooling shirt is a practical device for SOF during SUSOPS. Hence, testing this product's effectiveness in maintaining or reducing core body temperature and enhancing human performance fulfilled an Air Force Special Operations Command research gap related to exertional heat illness. The independent variable for this study was the cooling shirt technology and the dependent variables included core body temperature, exercise heart rate, physical work capacity test, capillary blood lactate level, and subjective ratings of perceived exertion.

There were two statistically significant differences with respect to core body temperature during the 70-minute weighted-vest walking test. Peak and core body temperatures were 0.26˚F and 0.27˚F less when the subjects were exercising in the loaded state, respectively ($p < .05$). No statistically significant differences were found in blood lactate level, number of sandbag shuttles completed in 10 minutes, or participants' subjective ratings of perceived exertion.

Discussion

The primary aim of this study was to determine the effects of a cooling shirt with passive cooling inserts on core body temperature during high-intensity physical activity on a treadmill. A secondary interest was to determine the effects of a cooling shirt on physical work capacity (e.g., sandbag shuttle) and various other physiological parameters related to physical performance. Examination of the effects of this cooling technology substantiated its role in mitigating heat-related illnesses and improving physical performance in a like group of SOF in a controlled laboratory environment. Most cooling technologies must either be frozen or contain a form of cooling crystals or gel packs that are enclosed within fabric and are activated by soaking in water or by pressing a sensor attached to a cooling vest. The cooling effects provided are minimal and are not sustained, especially when SOF are exposed to hot, humid conditions during SUSOPS missions.

Conclusion

The results from this investigation showed reduced core and peak core body temperatures while using the "loaded" shirt with the cooling inserts. Future research will focus on additional field studies and test the effectiveness of the cooling shirt on flight maintenance, aircrew, and emergency flight surgeons in non–air-conditioned rooms overseas. Additional field studies are warranted to determine the passive cooling shirt's ability to cool while completely covered (e.g., under ABUs and body armor).

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