Effects of a Cooling Vest on Core and Skin Temperature Following a Heat Stress Trial in Healthy Males

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Abstract: The purpose of this study was to examine the effects of a cooling vest on core body temperature following active dehydration and hyperthermia induced by exercising in a hot, humid environment. Based on our study, we recommend the ClimaTech HeatShield™ only when athletes present with mild symptoms of heat exhaustion.

Fluid replacement and the prevention of heat illness have been prevalent topics in recent athletic training literature (Bailes, Cantu, & Day, 2002). Incidences of fatal collapse or heat illness in athletes have brought this topic to the forefront in the field of athletic training (Bailes et al., 2002). An inherent risk of dehydration and heat illness exists in physically active individuals, particularly when performing in hot, humid environments (Binkley, Becket, Casa, Kleiner, & Plummer, 2002). An athletic trainer's ability to recognize and manage heat-related emergencies is crucial in preventing a catastrophic event. Exertional heatstroke, the most serious heat illness, is a life-threatening medical emergency characterized by progressive weakness, fatigue, and hyperthermia (Armstrong, 2000). Elevated core body temperature is common in individuals exercising in a hot, humid environment and could potentially lead to a dangerous condition of exertional hyperthermia (Clapp, Bishop, Muir, & Walker, 2001). Numerous researchers (Binkley et al., 2002; Germain, Jobin, & Cabanac, 1987; Weiner & Khogali, 1980) have investigated the best methods of rapidly cooling core body temperature in order to determine the most effective method for athletic trainers and other health professionals to utilize in an emergency situation.

Differentiating between heat exhaustion and heat stroke is imperative in determining the proper care and management of a potentially fatal circumstance. Heat exhaustion is the most common type of heat illness (Binkley et al., 2002) and is commonly defined as the inability to continue exercise in the heat (Armstrong, 2000; Binkley et al., 2002). Heat exhaustion is characterized by pallor, fainting, weakness, dizziness, headache, and a core body temperature that ranges between 36 ^{o}C and 40 ^{o}C (Binkley et al., 2002). Heat stroke, however, can be distinguished from heat exhaustion by the presence of a dangerously high core body temperature (rectal temperature higher than 40.0 ^{o}C), or hyperthermia (Armstrong, 2000). With heat stroke, the presence of other signs and symptoms associated with organ system failure due to the hyperthermia is also evident (Armstrong, 2000).

Controversy exists regarding the most effective means of rapidly cooling hyperthermia associated with heat stroke. To date, ice water immersion is considered to be the gold standard for treating hyperthermia and heat stroke. Aside from conventional cooling methods, such as ice packs or ice water immersion, a myriad of adjunctive cooling modalities have emerged into the athletic and industrial realms. Some of these cooling methods include water spray, warm air spray, face fanning, helicopter rotary blade downdraft, whole-body liquid cooling garments, head cooling units, cooling vests, ice packs or towels, cold water immersion, and ice water immersion (Clapp et al., 2001; Clements et al., 2002; Corcoran, 2002; Costrini, 1990; Desruelle & Candas, 2000; Germain et al., 1987; Weiner & Khogali, 1980). Determining the effectiveness of these cooling modalities is imperative in preventing a catastrophic event. Athletic trainers must remain up-to-date on current research findings on the most effective rapid cooling methods for the treatment of heat stroke as well as the effectiveness of new products on the market. The purpose of this study was to determine the efficacy of a cooling vest on core body temperature following active dehydration and hyperthermia induced by exercise in a hot, humid environment. Although participants in this study did not reach a dangerously high level of hyperthermia as is evident with heat stroke, the cooling vest was expected to rapidly reduce core body temperature as would be necessary when treating heat stroke.

Method

Research Design

The research design consisted of a randomized control design with two experimental groups. Ten participants were randomly assigned (n = 5) to either an experimental cooling vest (V) or a control no vest (NV) group. Dependent variables were core (rectal) body temperature, skin temperature, time to return to baseline core body temperature, percent body mass lost, urine color, urine specific gravity, and environmental conditions (ambient temperature and relative humidity). Dependent variables were measured throughout the heat stress trial and recovery periods. Potential participants reported to the Sports Science Research Laboratory at Florida International University (FIU) for a familiarization session, during which the informed consent form was read and signed and demographic information, a health history questionnaire, and baseline nude body mass were recorded. Participants were instructed to return to the laboratory at 09:30 the following day wearing an athletic supporter, mesh shorts, a cotton t-shirt, sweat socks, and running shoes. Participants were also instructed to consume a light breakfast of a bagel or toast and a small glass of juice.

Prior to the heat stress trial, participants' completely voided urine and nude body mass, urine color, and urine specific gravity data were recorded. A euhydration (normally hydrated) body mass was confirmed as less than $\pm$1% (or 0.4 kg) of baseline body mass. Participants performed the heat stress trial until a 3.27 $\pm$.08% body mass loss (mean = 67 $\pm$10.6 min, range = 55 - 85 min) was achieved. Throughout the heat stress trial and recovery, core body temperature and skin temperature were monitored at 5-min intervals. Following the heat stress trial, participants removed all clothing, toweled dry, voided urine, and the criterion body mass loss of at least 3% was confirmed. Post-exercise urine color and specific gravity data were recorded. The recovery period consisted of dehydrated and hyperthermic (core body temperature above baseline) participants resting in a thermoneutral environment (26.6 $\pm$2.2 ^{o}C; 55.4$\pm$ 5.8 % relative humidity) in either the V or the NV condition. Participants in the V group were fitted with the ClimaTech® cooling vest over a dry t-shirt and the NV group rested in their exercise clothes during recovery. At the end of the data collection session, dehydrated participants were required to orally rehydrate with cool water until they returned to within 2% of their pre-exercise body mass.

Participants

Participants were 10 healthy male volunteers (age = 25.6 $\pm$1.6 years, body mass = 80.3 $\pm$4.4 kg) recruited from FIU and surrounding community. Prior to the study, participants completed a health history questionnaire and informed consent form approved by the Florida International University Institutional Review Board. Potential participants were screened to ensure that they had no history of heat-induced illness, no chronic health problems, no orthopedic limitations, and no history of cardiovascular, metabolic, or respiratory disease within the past year. Males were selected to reduce the variability of ovarian hormone levels and substrate utilization between genders during exercise (Cleary, Kimura, Sitler, & Kendrick, 2002). During a familiarization session the day before testing, participants were instructed not to ingest alcohol, caffeine, non-prescription medication, and avoid dehydrating behaviors (sauna, diuretics, sweat suits, etc.) for the duration of the study.

Instruments and Procedures

Hydration measures. Dehydration was determined by measuring body mass, urine color, and urine specific gravity. Body mass was measured using a digital medical platform scale (model BWB-800S, Tanita Inc., Brooklyn, NY) consisting of a digital display monitor connected to the scale platform via a 1.83 m cord. The digital medical platform scale has a body mass capacity of 200 kg with accuracy to the nearest 0.1 kg. The scale was placed on a hard, level floor and calibrated with certified weights before the data collection session. Nude body mass was verified as participants entered a private room, disrobed, and stood on the scale while the investigator read the remote display from the cord under the door. Clothed body mass was determined with participants wearing running clothes, heart rate monitor (Polar Electro Inc., Woodbury, NY) and thermistors. Nylon mesh shorts, socks, and running shoes were worn to minimize the amount of sweat trapped in the clothing. Dry mass of participants' clothes and thermistors was subtracted from the clothed mass to estimate percent body mass loss during the heat stress trial. Actual percent body mass loss was determined from the nude pre- and post-exercise body mass measurements.

Urine specific gravity was measured using a clinical refractometer (model 300CL Atago Inc., Japan). Calibration of the clinical refractometer was performed prior to the first sample following manufacturer's instructions. A urine color chart was used to determine urine concentration with closest color on the chart or half point color recorded. Urine specific gravity and urine color are considered valid and reliable indicators of urine concentration (Armstrong, 2000).

Thermoregulatory responses. Core body temperature and mean skin temperature were determined to identify the hyperthermic condition and return to the normothermic (baseline body temperature) condition. Core body temperature was measured using a rectal probe (YSI 401, Yellow Springs Instruments Inc., Dayton, OH). Skin temperature was determined using skin thermistors (model 408/708, YSI.) taped to the arm, thigh, and calf. Chest thermistors were not used since the cooling vest covering these areas would elicit an abnormally low skin temperature; thus, unweighted mean skin temperatures were calculated using only the arm, thigh, and calf data.

Heat stress trial. The heat stress trial was performed to induce dehydration and hyperthermia during exercise in a hot, humid environment. Exercise was performed on a motor driven treadmill (Proform model, Icon Health & Fitness, Logan, UT) located outside in a hot, humid, subtropical climate (mean ambient temperature = 33.1 $\pm$3.1 ^{o}C, range = 28.5 – 40.5 ^{o}C; relative humidity = 55.1 $\pm$8.9%, range = 40.7 – 68.1%; and wind speed = 2.1 $\pm$1.1 km·hr^{-1}, range = .3 – 4.2 km·hr^{-1}). The heat stress trial commenced with a 5-min warm-up at 40% of each participant's age predicted heart rate range (mean heart rate = 131 $\pm$27 beats per min). Treadmill speed was then increased, and participants exercised at 60% of the age predicted heart rate range (mean heart rate = 156 $\pm$7 beats per min). A 60-s rest was administered every 15 min of exercise. As safety precautions, heart rate and mean arterial pressure were taken within the first

10 min of exercise; core body temperature was monitored every 5 min. Although no participant had severe hyperthermia, if core body temperature exceeded 39.0 °C, the heat stress trial was terminated.

Cooling vests. The experimental V group was fitted with a superficial cooling garment during the recovery period. The HeatShield™ cooling vest (ClimaTech Safety Inc., White Stone, VA) is a superficial cooling garment consisting of an outer shell made of Indura UltraSoft® fireproof cotton blend fabric. Beneath this outer shell lies a radiant heat reflective material, a layer of insulation, the patented synthetic ice core, and a hydrophobic quilted layer next to the body. These layers are stitched together with Nomex® thread. The cooling vest is designed for firefighters, hazardous materials teams, and mobile personnel exposed to extreme heat conditions. When following manufacturer's instructions, the HeatShield™ cooling vest can maintain a 21.1 °C environment in 37.8 °C conditions for approximately 3.5 hr.

Statistical Analysis

Statistical analyses were conducted on the hydration measures (percent body mass lost, urine color, urine specific gravity), core body temperature, arm skin temperature, and environmental conditions (ambient temperature and relative humidity) data. Pre- and post-heat stress trial differences in hydration measures were compared using separate dependent t-tests. Differences between the V and NV groups in core body temperature during the heat stress trial and recovery period were compared using separate independent t-tests. Separate 2 (V and NV) x 2 (time) ANOVAs with repeated measures on the time factor were performed for the final data collection times during the heat stress trial and recovery period for both groups. Descriptive statistics were performed for the environmental conditions measures. Data were analyzed using the SPSS 11.0 statistical package and significance was set at $P \leq .05$ for all analyses.

Results

Thermoregulatory Responses

Hydration measures. Measures of hydration status were compared between the pre- and post-heat stress trial periods. No significant differences between the V and NV groups (t_8 = -2.030, P = .077) were found on percent body mass lost data. Neither urine color ($F_{1,8}$ = 1.785, p = .218, power = .218) nor urine specific gravity ($F_{1,8}$ = .010, p = .923, power = .051) were significantly different between groups, but both were significantly higher (urine color, $F_{1,8}$ = 36.915, $p \leq .001$, power = .999; urine specific gravity, $F_{1,8}$ = 6.090, p = .039, power = .582) post-heat stress trial than pre-heat stress trial.

Thermoregulatory responses. Comparisons between the V and NV groups for core body temperature between 0 and 60 min of the heat stress trial revealed no significant differences between groups ($F_{1,8}$ = 1.785, p = .218, power = .218); however, differences between tests were significant ($F_{1,8}$ = 138.001, $p \leq .001$, power = 1.000). Core body temperature increased 3.3% or 1.3 °C from 0 to 60 min (37.4 $\pm$0.2 °C and 38.7 $\pm$0.2 °C, respectively) of the heat stress trial. During the recovery period, no significant differences in core body temperature between the V and NV groups were found ($F_{1,8}$ = .815, p = .393, power = .126); however differences between tests were significant ($F_{1,8}$ = 166.018, $p \leq .001$, power = 1.000). Core body temperature was decreased 2.6% or 1.0 °C from 0 to 30 min (38.8 $\pm$0.3 °C and 37.8 $\pm$0.3 °C, respectively) of the recovery period.

Potentially clinically relevant, although not significant, differences did exist during the post-heat stress trial recovery period. Specifically, the difference in core body temperature from 0 min to the end of the recovery period (mean time for return to baseline = 50.2 $\pm$17.05 min, range = 28 – 80 min) was 10.1% lower for the V group (-1.29 $\pm$.33 °C) than for the NV group (-1.44 $\pm$.39 °C). Although not significant (t_8 = 1.219, p = .258), the time for return to baseline core body temperature during the recovery period was 22.6% faster for the V (43.8 +15.1 min) group than for the NV (56.6 +18.0 min) group. Finally, the rate of core body temperature decrease during the recovery period (t_8 = .343, p = .740) was 6.7% faster for the V (.030 $\pm$.010 $°C \cdot min^{-1}$) group than for the NV group (.028 $\pm$.008 $°C \cdot min^{-1}$).

Mean arm skin temperature comparisons were performed for the V and NV groups for the heat stress trial and recovery periods. No significant ($F_{1,8}$ = 5.118, p = .054, power = .390) difference was found between the V and NV groups in mean arm skin temperature. However, mean arm temperature was significantly ($F_{1,8}$ = 31.623, $p \leq .001$, power = .998) decreased 5.51% from the heat stress trial (mean skin temperature = 36.1 $\pm$0.9 °C) compared to the recovery period (mean skin temperature = 34.2 $\pm$0.7 °C).

Environmental conditions. The environmental conditions measured during the heat stress trial and the recovery periods were ambient temperature and relative humidity. Environmental conditions during the heat stress trial were mean ambient temperature = 33.1 $\pm$3.1 °C, mean relative humidity = 55.1 $\pm$8.9%, and mean wind speed = 2.07 $\pm$1.1 $km \cdot hr^{-1}$. During the recovery period, environmental conditions were mean ambient temperature = 26.6 $\pm$2.1 °C and mean relative humidity = 55.3 $\pm$5.8%.

Discussion

The purpose of this study was to examine the efficacy of a cooling vest on reducing core body temperature following active dehydration and hyperthermia induced by exercising in a hot, humid environment. Because of the various adjunctive cooling therapies available today, athletic trainers should be knowledgeable of the best clinical practice for rapidly cooling a hyperthermic athlete. Therefore, this study determined the thermophysiological impact and clinical application of a cooling vest on cooling mild hyperthermia. Both the V and NV groups had similar core body temperatures at 0 min of recovery; however, although not significant, the cooling rate for the V group was faster than the control group. The time for return to baseline core body temperature during the recovery period was 22.6% faster for the V group (43.8 $\pm$15.1 min) than for the NV group (56.6 $\pm$18.0 min). Also not significant, the rate of core body temperature decrease during the recovery period was 6.7% faster for the V group (.030 $\pm$.010 $°C \cdot min^{-1}$) than for the NV group (.028 $\pm$.008 $°C \cdot min^{-1}$). Although participants wearing the vest during recovery had reduced core body temperature in a shorter period of time than participants who did not wear the vest, the findings were not significant. Our findings did not support our hypothesis that the cooling vest would rapidly cool core body temperatures in mildly hyperthermic individuals. We conclude that the cooling vest is not as effective as the gold standard of ice water immersion in rapidly reducing core body temperature. Our study's findings support the body of evidence provided by previous studies that have demonstrated that ice-water immersion is the fastest and most effective method of reducing core body temperature in hyperthermic individuals (Armstrong, 2000; Binkley et al., 2002; Casa & Armstrong, 2003; Clapp et al., 2001; Clements et al., 2002; Costrini, 1990; Roberts, 1998; Sandor, 1997). The findings of the current study support previous studies comparing the use of a cooling garment, whole-body immersion, and torso-only immersion on 10 participants with mild hyperthermia (Clapp et al., 2001).

Although the differences between the V and NV groups in terms of core body temperature were not significant, a noticeable increase in cooling rate was observed in participants wearing the HeatShield™ cooling vest manufactured by Climatech Safety, Inc. Also, participants who wore the cooling vest during the recovery period reported positive psychological effects including a feeling of coolness and a soothing effect. These effects were also reported by Greenleaf et al. (1980) whose participants were cooled using a liquid-cooled neoprene headgear following exercise in a hot, humid environment.

Compared to other adjunctive cooling modalities, such as a whole-body cooling garment requiring connection to a large cooling unit or source of electrical power, the HeatShield™ is more practical and easier to use. Because the HeatShield™ can maintain its cool temperature in a freezer or ice chest, it can be easily accessible or even kept on the field. Since the Heat-Shield™ is portable and easy to place on an athlete, it may be considered a practical cooling modality for an athlete experiencing signs of mild heat exhaustion, such as nausea, lightheadedness, and pallor. The HeatShield™ can easily be used to treat heat exhaustion at track events or other outdoor events where there is no opportunity to move the athlete indoors. The HeatShield™ would be advantageous at football events where there are no air-conditioned facilities. The athletic trainer can remove an athlete's shoulder pads and easily place the HeatShield™ on the athlete. Based on the findings of the current study, the HeatShield™ is not recommended for an athlete experiencing signs of exertional heat stroke in which elevated core body temperatures must be reduced as soon as possible.

We acknowledge there were some limitations to this study. It should be noted that our small sample size (*N*=10) was a limitation in our study. However, this is similar to Clapp et al. (2001) whose small sample size (*N*=5) resulted in an insufficient power and large effect sizes. Despite a small sample size, we were able to conclude that the cooling vest does not rapidly cool core body temperatures. For ethical and safety concerns, the extent of the heat stress trial in the current study was limited to elicit only mild hyperthermia of rectal temperatures less than 39.0 ^{o}C. Similar to findings from Clapp et al. (2001) and Clements et al. (2002), our limitation of the extent hyperthermia in our participants did not reflect the extreme conditions in which many athletes compete. The hyperthermia induced by our heat stress trial was not as extreme as that normally found in athletes with exertional heatstroke (rectal temperatures exceeding 41.0 ^{o}C) (Clapp et al., 2001). Our findings support the recommendation that the cooling vest should not be used in the treatment of heat stroke. Based on the findings of our study, we recommend using the ClimaTech HeatShield™ only when an athlete presents with mild symptoms of heat exhaustion. Ice-water immersion or alternate methods of cooling such as ice packs should continue to be considered the cooling modalities of choice when treating an athlete who presents with hyperthermia and requires rapid reduction of core body temperature.

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