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Wearing body armor increases physiologic strain in Soldiers operating in warm and hot environments. This increased heat strain is due to inhibited air circulation to the torso and increased insulation. Increased heat strain results in compromised work capacity and may lead to serious heat injuries or mission failure. Microclimate cooling systems (MCCS) are used to mitigate these problems in a number of situations for the mounted Soldier, such as helicopter flight crew or armored vehicle crew. The U.S. Army is actively pursuing candidate MCCS that can be used by the dismounted Soldier in hot weather operations. The Product Manager for Soldier Survivability (PM-SSV) of the Program Executive Office, Soldier (PEO-Soldier) requested the Soldier Battle Lab (SBL) of the U.S. Army Infantry Center, Ft. Benning, conduct a Soldier Protection Demonstration. The principal focus of this demonstration was to collect user input evaluations of commercially available lightweight MCCS worn during routine dismounted activities. There were additionally six critical operational issues addressed by the demonstration: 1) Does the candidate system affect the Soldier's core body temperature? 2) Does the candidate system affect a Soldier's ability to fight? 3) Does the candidate system affect Soldier

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# SOLDIER PROTECTION DEMONSTRATION III – FIELD TESTING AND ANALYSIS OF PERSONAL COOLING SYSTEMS FOR HEAT MITIGATION

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The authors wish to thank the Soldiers from the 11th Armored Cavalry Regiment at Ft. Irwin, whose voluntary participation and commitment were responsible for the success of this Soldier Protection Demonstration.

## EXECUTIVE SUMMARY

Wearing body armor increases physiologic strain in Soldiers operating in warm and hot environments. This increased heat strain is due to inhibited air circulation to the torso and increased insulation. Increased heat strain results in compromised work capacity and may lead to serious heat injuries or mission failure. Microclimate cooling systems (MCCS) are used to mitigate these problems in a number of situations for the mounted Soldier, such as helicopter flight crew or armored vehicle crew. The U.S. Army is actively pursuing candidate MCCS that can be used by the dismounted Soldier in hot weather operations. The Product Manager for Soldier Survivability (PM-SSV) of the Program Executive Office, Soldier (PEO-Soldier) requested the Soldier Battle Lab (SBL) of the U.S. Army Infantry Center, Ft. Benning, conduct a Soldier Protection Demonstration. The principal focus of this demonstration was to collect user input evaluations of commercially available lightweight MCCS worn during routine dismounted activities. There were additionally six critical operational issues addressed by the demonstration: 1) Does the candidate system affect the Soldier's core body temperature? 2) Does the candidate system affect a Soldier's ability to fight? 3) Does the candidate system affect Soldier protection? 4) Is the candidate system suitable to wear in an operational environment? 5) Is the candidate system compatible with current weapons and equipment? and 6) Does the candidate system affect Soldier mobility? Two candidate personal cooling systems (PCS) were selected for the demonstration based on the main parameter of being lightweight. The demonstration was conducted in the desert at Ft. Irwin, CA, during daytime hours in late August 2007. U.S. Army Research Institute of Environmental Medicine (USARIEM) personnel were requested to provide on-site support for human volunteer safety during tests as safety consultants on issues of heat strain, to brief volunteers on the use of the VitalSense Core Temperature Pills, to provide informed consent, and to oversee real-time core temperature monitoring. USARIEM personnel administered core body temperature sensors to the volunteers each day, ensured that data were being collected and stored, and provided core temperature data to SBL after each day's testing. Soldiers were divided among three, 4-5 member teams, and each team was scheduled to test a different randomly assigned PCS configuration each day. The volunteers completed five events each day. These events were compatibility testing, individual movement technique on an obstacle course, a road march, a vehicle patrol, and a live fire exercise. The principle finding with the core temperature pills was that while there were four instances of subjects exceeding a core temperature of 39.0°C, no subject reached the cutoff temperature of 39.5°C. The design used in the SPD3 was useful for determining the overall comfort of wearing the candidate cooling systems and their compatibility with the Soldiers' other equipment, as well as their compatibility with performing common military tasks. In regards to core temperature, no determination could be made on whether the systems provided effective cooling versus a no cooling control, or whether one system was more effective than the other.

## INTRODUCTION

Wearing body armor increases physiologic strain in Soldiers operating in warm and hot environments. Previous data indicate body armor increases the effect of the wet bulb, globe temperature (WBGT) index by ~2.8°C compared to wearing only the standard Battle Dress Uniform (BDU) (1, 3). This increased heat strain is due to inhibited air circulation to the torso and increased insulation. Increased heat strain results in compromised work capacity and may lead to serious heat injuries or mission failure.

Microclimate cooling systems (MCCS) are used to mitigate these problems in a number of situations for the mounted Soldier, such as helicopter flight crew or armored vehicle crew. The bulk and weight of MCCS has made them a poor solution for dismounted Soldiers except in specialized occupations such as HAZMAT teams or bomb squad members. The U.S. Army is actively pursuing candidate MCCS that can be used by the dismounted Soldier in hot weather operations.

As part of this process, the Product Manager for Soldier Survivability (PM-SSV) of the Program Executive Office, Soldier (PEO-Soldier) requested the Soldier Battle Lab (SBL) of the U.S. Army Infantry Center, Ft. Benning, conduct a Soldier Protection Demonstration. The principal focus of this demonstration was to collect user input evaluations of commercially available lightweight MCCS worn during routine dismounted activities. The candidate MCCS were required to meet strict parameters on overall weight among a large list of desired capabilities. There were additionally six critical operational issues addressed by the demonstration: 1) Does the candidate system affect the Soldier's core body temperature? 2) Does the candidate system affect a Soldier's ability to fight? 3) Does the candidate system affect Soldier protection? 4) Is the candidate system suitable to wear in an operational environment? 5) Is the candidate system compatible with current weapons and equipment? and 6) Does the candidate system affect Soldier mobility?

The SBL designed the Soldier Protection Demonstration III (SPD3) to address these principal concerns regarding two candidate personal cooling systems (PCS) that were selected for the demonstration based on the main parameter of being lightweight.

The demonstration was conducted in the desert at Ft. Irwin, CA, during daytime hours in late August 2007.

U.S. Army Research Institute of Environmental Medicine (USARIEM) personnel were requested to provide on-site support for human volunteer safety during tests as safety consultants on issues of heat strain, to brief volunteers on the use of the VitalSense Core Temperature Pills to provide informed consent, and to oversee real-time core temperature monitoring. USARIEM personnel administered core body temperature sensors to the volunteers each day, ensured that data were being collected and stored, and provided core temperature data to SBL after each day's testing.

## METHODS

### PRE-DEMONSTRATION DATA COLLECTION AND PROCEDURES

Fourteen Soldiers from the 11th Armored Cavalry Regiment at Ft. Irwin were selected to participate, although one Soldier was removed from testing due to prior injury. Demographics and anthropometric measurements were collected, and Soldiers were provided new equipment training. Credentialed USARIEM personnel briefed volunteers on the use of the Vital Sense core temperature sensor, including any exclusions or contraindications. If volunteers were unable to swallow the sensor but still chose to take part in the demonstration, they were given the option to use the sensor as a suppository. At the conclusion of the briefing, volunteers were given the opportunity to ask as many questions as necessary to feel satisfied that they understood the risks and benefits of taking part in SPD3. The volunteers who chose to participate signed the informed consent.

### CLOTHING AND EQUIPMENT

The New Equipment Training Team (NET) briefed the volunteers on all new equipment prior to testing. During testing, Soldiers wore The Army Combat Uniform (ACU) with the Army Combat Shirt under the Improved Outer Tactical Vest (IOTV) instead of the regular ACU top. Volunteers performed testing on three consecutive days. Each day consisted of wearing one of three configurations including a baseline control and two candidate PCS. The configurations were designated as BL (Combat Shirt and IOTV only), System A (Global Secure ambient air ventilation system), and System B (First Line phase change system), respectively. Additional equipment carried by each Soldier included a Vital Sense Monitor (VSM), camelback, Kevlar helmet, unloaded M16 rifle, Polar heart rate chest strap and monitor, and ammunition pouches.

### CORE TEMPERATURE

Each morning between 0730 and 0830 h, Soldiers were administered a core body temperature sensor and an orange “MRI incompatible” warning band was placed on their wrist. Proper function of sensors and monitors was verified by USARIEM personnel prior to ingestion and testing. Figure 1 shows the sensor set-up prior to administration each morning. On day 3, if a Soldier still had two sensors remaining in their gastrointestinal system, no sensor was administered. Each volunteer had a VSM affixed to their IOTV to record core temperature every minute throughout the testing day. The manufacturer (Mini Mitter, Respironics, Bend, OR) suggests a minimum of 4 h after ingestion for the temperature sensors to move beyond the stomach and into the small intestine; therefore, while core temperatures were monitored for safety prior to the lunch break, there was awareness that temperatures could be affected by food and fluid ingestion during this time period. If a Soldier had more than one sensor in their gut, both temperatures were recorded and provided to SBL. USARIEM personnel carried additional VSMs in medic mode and monitored and recorded core temperatures throughout all testing. All values collected on the VSM were used for safety monitoring

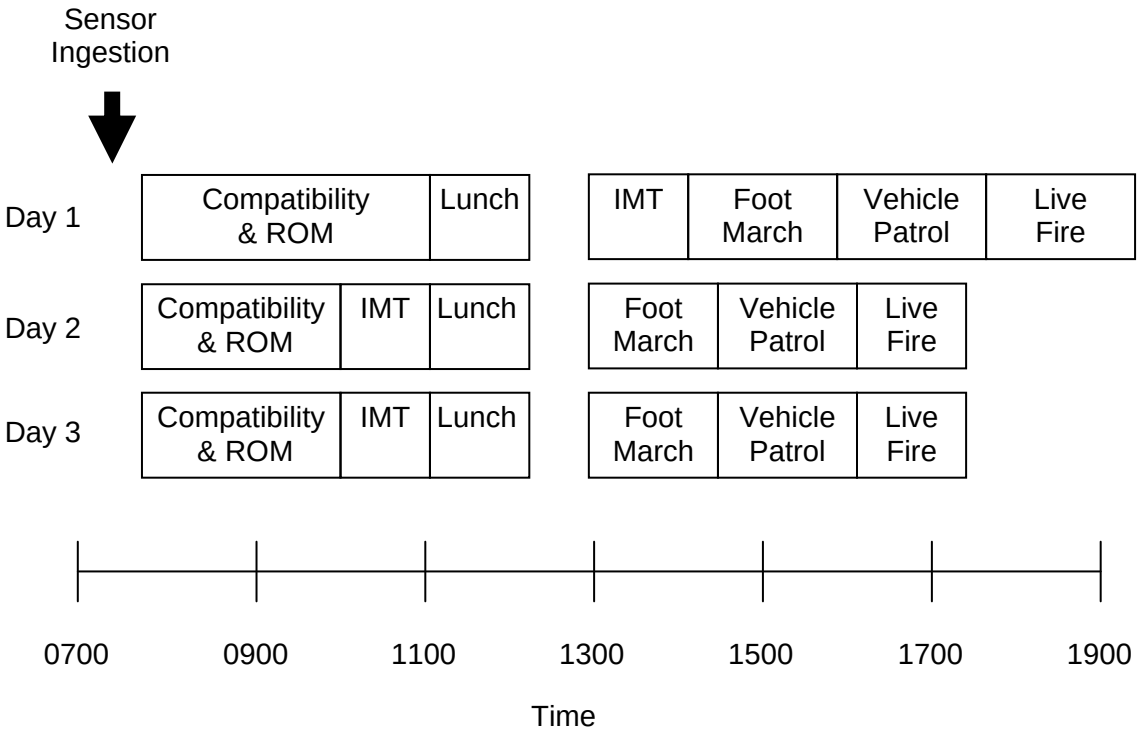
and not to compare relative value of the PCS, as SPD3 was not designed to allow for definitive statistical analysis of core temperature data. One medic mode VSM remained with the 11th Armored Cavalry Regiment to ensure that sensors properly passed through Soldiers' digestive systems after the conclusion of testing.

Figure 1. Telemetry system setup prior to sensor administration

## DEMONSTRATION DESIGN AND EXECUTION

Soldiers were divided among three, 4-5 member teams and each team was scheduled to test a different randomly assigned PCS configuration each day. The volunteers completed five events each day. The order of events was similar for all 3 days and is illustrated in Figure 2. After each test event throughout the day, Soldiers completed questionnaires regarding compatibility and likeability. Volunteers took a 60 min lunch break each day from 1200 h to 1300 h and were given no food restrictions.

Figure 2. Timeline depicting the daily schedule of events for the volunteers



Event 1 consisted of testing compatibility of the two PCS with existing equipment and range of motion while completing standard military tasks. The event consisted of completing a series of short duration tasks such as employing a grenade, weapons firing, and low crawl conducted both outdoors in the shade and in an air-conditioned building to rate the compatibility of each PCS with standard issued military equipment. At the completion of each task the volunteers filled out questionnaires regarding the compatibility of the PCS with standard equipment while completing the tasks. Figure 3 shows a volunteer performing a compatibility test while using her weapon.

Figure 3. Soldier aiming weapon during compatibility test

Event 2 consisted of an Obstacle Course (Individual Movement Technique-IMT). The course contained four tasks: log walk, post dodging, combat crawl, and hurdles. This event took place outdoors with no shade. Figure 4 shows two volunteers during the hurdles. On day 1, this event was completed after the daily lunch break. On the remaining two test days, this event was completed in the morning prior to the lunch break.

Figure 4. Soldiers clearing hurdles during obstacle course

Event 3 consisted of a 2-mile road march. The march was self-paced by the Team, and volunteers were provided cold water during a non-uniform break at the midpoint of the walk. Two USARIEM personnel monitored core temperatures before, during, and after the event for all three teams. Each day, one of the teams was monitored by a member of the NET team during the walk to ensure a VSM set to medic mode accompanied each team at all times. This event took place outdoors with no shade. Figure 5 shows one team setting out on a day's march.

Figure 5. Soldier team setting out on road march

Event 4 consisted of Vehicle Patrol exercise. Each team was scheduled to perform a hasty Traffic Control Point (TCP) and a hasty defense. On site, the design was altered to five dismount/mount operations, with all Soldiers operating all five positions in the vehicle: Driver, Troop Commander (TC), two passengers, and a gunner manning a M240/249 mounted on the turret. On testing day 1, Soldier core temperatures were monitored before the event, after the third dismount, and after the completion of the event. Results from day 1 showed only small temperature increases at the mid-point measurement, with no risk to the subjects, so this measurement was eliminated on the remaining two days to reduce interference with the mount/dismount operation. This event took place outdoors with shade provided only from the vehicle. Figure 6 shows volunteers during a vehicle patrol exercise.

Figure 6. Soldiers during vehicle patrol exercise

Event 5 consisted of a Live Fire Exercise on a Short Range Marksmanship Course (SRMC). The live fire exercise was designed to allow Soldiers to fire 32 rounds ranging at a distance of 5 m to 25 m. Testing day 1 included safety briefings and instructions that lasted approximately 60 min prior to the event. The briefings were not necessary for testing days 2 and 3. On test day 2, the range was not available and Soldiers performed other exercises such as military operations on urban terrain (MOUT), which included charging an objective and building assault. One Soldier was allowed to sit and treat blisters during the training on day 2. This event took place outdoors with intermittent shade. Figure 7 shows volunteers at the Short Range Marksmanship Course.

Figure 7. Soldiers during live fire exercise at the short range marksmanship course


## STATISTICAL ANALYSES

No core temperature statistical comparisons can be made between personal cooling systems. Differing event duration, start times and environmental conditions, as well as other non-controlled variables as noted above, preclude an analysis comparing the isolated effects of personal cooling systems on core temperature. Due to these constraints, no mean temperature values are presented.

## RESULTS

One Soldier who participated on the first day was not able to participate on subsequent days due to the inability to ingest additional temperature sensors.

Throughout testing, temperature values prior to lunch from sensors swallowed that morning were varied due to effects of fluid ingestion, and so are not presented. Therefore, none of the graphs show results from event 1, the compatibility tests, and graphs for days 2 and 3 do not show results from event 2, the IMT, which was moved to the morning on these two days.

During the three days of the demonstration, no Soldier reached the core temperature safety limit of 39.5°C. Three volunteers' core temperatures did exceed 39.0°C during the road march. One volunteer reached a maximum temperature of 39.20°C during the road march while wearing candidate system A (ambient air). One volunteer reached a maximum temperature of 39.24°C during the road march while wearing candidate system B (phase change). Finally, one volunteer reached a core temperature of 39.19°C and 39.12°C on two days during the road march while wearing system B and system BL (baseline), respectively. The core temperatures above 39.0°C on this last subject were not taken from the core temperature pill swallowed on the day of the test, but rather by using the readings from a sensor pill still in the GI tract from the previous day.

The range of time to complete the obstacle course was 5-6 min and was the same for all three days. The environmental temperature during this activity ranged from 37.8°C to 43.3°C over the three days.

The range of time to complete the road march over the three test days was approximately 45 min to 67 min. The environmental temperature during this activity ranged from 38.9°C to 46.1°C over the three days.

The range of time to complete the vehicle patrol over the three test days was approximately 15 min to 31 min. The environmental temperature during this activity ranged from 39.4°C to 46.1°C over the three days.

The range of time to complete the live fire exercise over the three test days was approximately 65 min to 110 min. The environmental temperature for this activity ranged from 40.0°C to 44.4°C over the three days.

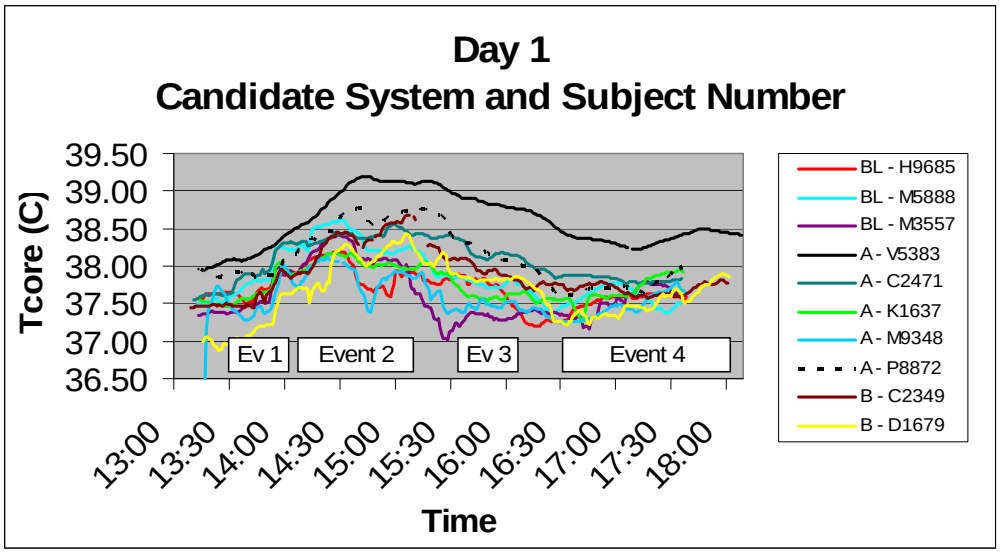
Individual core temperature values by time are presented in Figure 8. These graphs represent values of core temperature pills taken on the day of testing. Curves showing core temperatures above 39.0°C are not shown for volunteer P8872 because these values were recorded from pills still in the GI system more than 24 h after ingestion. Several volunteer's core temperatures were affected by cold fluid ingestion and are not graphically presented. The missing volunteers for day 1 are A0751, P1957, and L3770.

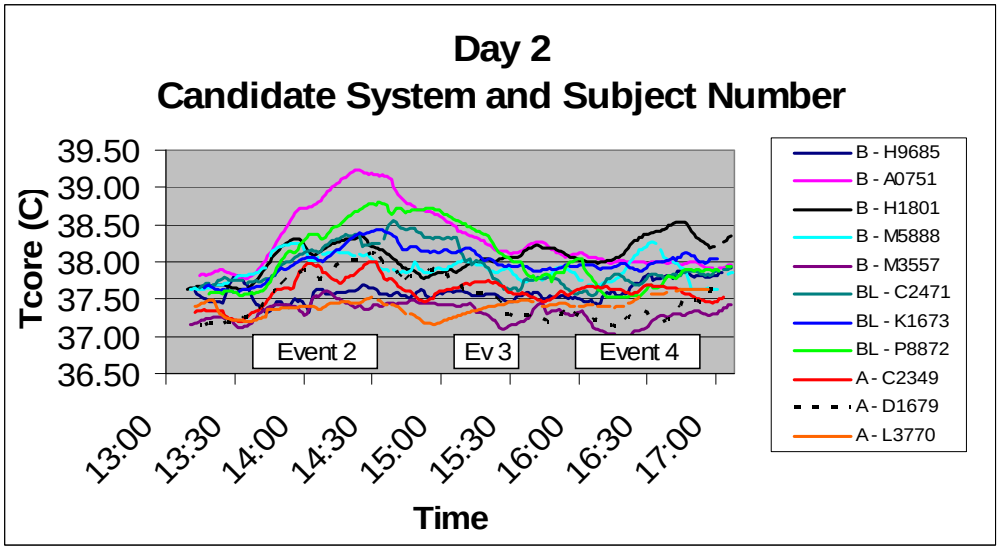
The missing volunteers for day 2 are V5383 and P1957. The missing volunteers for day 3 are M5888, M3557, V5383, K1673, and P8872.

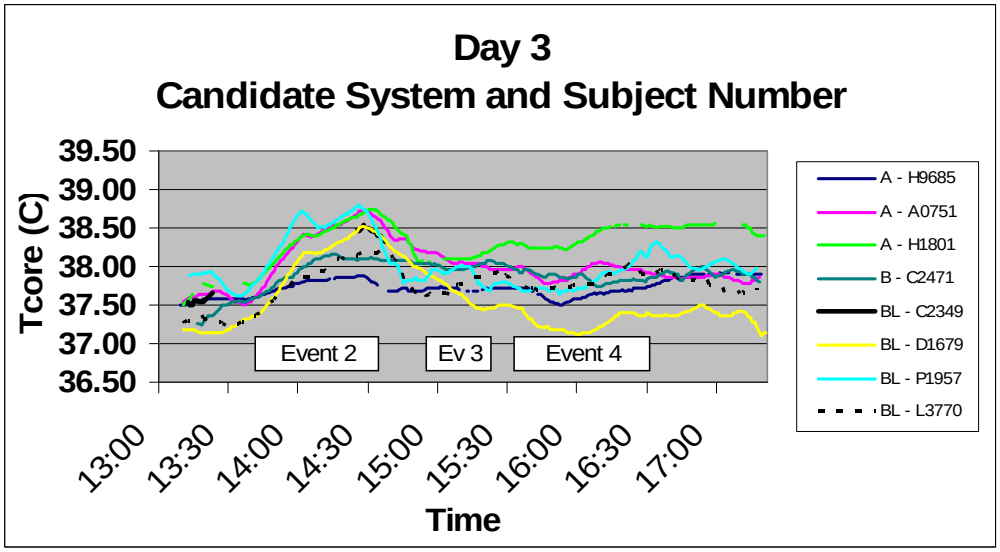
## DATA TRANSFER

Each morning USARIEM personnel provided the SBL with core temperature data from the previous day. On the final day, all core temperature values were transferred in the afternoon to complete the USARIEM task.

Figure 8 (days 1-3). Individual core temperature values by time.
Candidate system identified by A, B, BL.
Event 1=IMT, Event 2=Road March, Event 3=Vehicle Patrol, Event 4=Live Fire.



# DISCUSSION

## CORE TEMPERATURES

Over the three day demonstration period, afternoon core temperature measures were successfully collected for all but one volunteer. A battery failure in that Soldier's individual VSM caused the loss of data; however, the ingested sensor remained active, and the Soldier's core temperature was monitored for safety purposes for the duration of testing. We observed transient decreases in temperature readings for all volunteers when consuming cold fluids during the morning activities.

## TELEMETRY SENSOR READINGS

Although the VSM allows for easy and quick data transfer to a computer, the raw data were not useful for analysis or graphical representation. Interpretation and processing of the raw data required physiological expertise and knowledge of the telemetry system to determine whether recorded values were true and accurate for interpretation. Analyzing the endogenous heat production and exogenous heat sources allowed for estimation of reasonable increases or decreases in core temperature. Only these values were included in the results. For example, a decrease in the core temperature measure may be the result of cool fluid ingestion or sensor malfunction instead of a true decrease in body core temperature if a volunteer is working in a warm or hot environment at a high intensity while wearing body armor. Values that did not follow an expected pattern for the environment and workload were excluded from the data.

## TELEMETRY SENSOR INGESTION TIMING

When periodic core temperature safety checks are necessary, it is important to ensure that telemetry sensors are ingested early enough to increase the probability that they have reached the small intestine. This is particularly important with volunteers exercising in extreme environmental conditions or at high intensity when the core temperature will likely rise beyond 39.0°C. Although the exact location of the sensor is difficult to determine due to individual differences in gastrointestinal motility, the manufacturer recommends waiting at least 4 h after ingestion before monitoring temperatures to assure movement beyond the stomach. One article in the current literature suggests ingesting a temperature sensor up to 10 h before activity to limit effects of fluid ingestion (4). During SPD3, we observed inaccurate readings up to 9 h post-ingestion in some volunteers, suggesting that sensors may require earlier ingestion times (>5 h) in order to insure accurate readings from all volunteers. Specifically, we made several observations where two simultaneous core temperature readings from a pair of telemetry sensors (ingested 24 h apart) were different by more than 2.0°C. A difference of this magnitude could have serious consequences on volunteer safety. Some volunteers had gastrointestinal transit times greater than 24 h and, therefore, had two sensors within their gut, which allowed both sensors to be tracked. Although the specific location of each sensor was unknown, we conclude that the sensor ingested greater than 24 h prior to

testing was more reliable/accurate and recommend that volunteers ingest sensors the evening prior to physical activity, when core temperature safety limits are a concern.

Although the preferred method of temperature sensor administration during SPD3 was oral ingestion, it is important to note that more accurate core temperature measurements may be collected via self administration of the sensor as a suppository immediately prior to activity. This method guarantees that the "gold standard" of core temperature measurement, rectal temperature, is recorded. The rectal suppository method also eliminates any temperature variation due to gastrointestinal motility and changing location. The only negative rationales for using sensors as a suppository are volunteer aversion and timing limitations due to excretion, as the sensor is lost with the first bowel movement.

## STUDY DESIGN AND FIELD TESTING

The design used in the SPD3 was useful to determine the overall comfort of wearing the candidate cooling systems and their compatibility with the Soldiers' other equipment, as well as their compatibility while performing common military tasks. In regards to core temperature, the variability in multiple testing parameters from day to day meant that no determination could be made on whether the systems provided effective cooling versus a no cooling control, or whether one system was more effective than the other.

Initial human testing of candidate cooling systems should be carried out under controlled laboratory conditions. These tests allow for precise control of nearly all variables including timing of events (circadian), food and fluid consumption, pacing, and rest periods, as well as environmental conditions. Controlling for these factors provides the most rigorous analysis for comparison of physiological variables, while still allowing for qualitative and subjective comparisons to be made. This allows for comparison of the cooling provided by the candidate systems, and down selection of those resulting in the most favorable physiological responses for improved Soldier performance and comfort. Further, ensuring that the physiological benefit of an MCCS exists through controlled laboratory testing can reduce the cost and manpower necessary to field test an MCCS that has no potential benefit. Candidate system A did undergo laboratory testing, and results on its efficacy have been published (2).

After laboratory testing is completed, a chosen number of candidate systems that provide a reasonable amount of cooling can be selected for a field demonstration or testing such as was performed in SPD3. In addition to gathering compatibility and likeability data, additional cooling data can also be analyzed if certain portions of the field test are controlled for metabolic rate. If an activity such as the foot march is conducted first, before the volunteers start to heat up, and it is conducted at a set rate for all volunteers, then comparisons can be made among the candidate systems. Environments will not be identical across the test days for this evaluation, but these differences can be accommodated in an analysis of covariance. While not as exact as a laboratory test, it will allow for a comparison of cooling effectiveness in a field setting. This type of analysis will

not be available for the self-paced events. However, the combination of laboratory testing to identify the candidate systems providing the best cooling, along with field testing to designate which systems are most compatible with Soldiers other clothing and equipment, and operational tasks will ultimately provide the Soldier with the best available item.

Considering the cost and manpower required for both laboratory and field testing for the acceptance of new equipment, it would be prudent to ensure that any physiological benefit provided by the candidate cooling systems is present and quantified prior to compatibility testing.

## SUMMARY

We were able to complete our mission to monitor the volunteers' core temperature for safety throughout the demonstration and to supply the SBL with copies of these data. However, we believe that core temperature and heart rate data that could have been used to help evaluate the relative effectiveness of the cooling systems were invalidated by the overall design of the demonstration. In the future, we recommend that personal cooling systems undergo experimental testing in three stages. First, equipment should undergo well-controlled laboratory analysis to determine that the system provides adequate cooling to warrant consideration for fielding. If the equipment satisfactorily meets the laboratory standard, it should undergo controlled field testing, as noted above, using volunteer personnel performing specific tasks. Physiological data such as heart rate and core temperature should be collected, as well as answers to questionnaires regarding the impact of the system on completing the tasks. Finally, field-hardened systems should be provided to troops conducting routine training operations, with structured comments collected on the perceived effectiveness, likeability, and compatibility of the system while in the field.

## REFERENCES

1. Cadarette, B. S., L. Blanchard, J. E. Staab, M. A. Kolka, and M. N. Sawka. *Heat Stress While Wearing Body Armor.* Natick, MA: USARIEM. Technical Report T01-9, 2001.

2. Chinevere, T. D., B. S. Cadarette, D. A. Goodman, B. R. Ely, S. N. Cheuvront, and M. N. Sawka. Efficacy of body ventilation system for reducing strain in warm and hot climates. *Eur. J. Appl. Physiol*. 103: 307-314, 2008.

3. Department of Army and Air Force. *U.S. Army, Heat Stress Control and Heat Casualty Management.* Department of Army and Air Force Technical Bulletin. Washington, D.C., TBMED507/AFPAM 48-152(1), 2003

4. Wilkinson, D. M., J. M. Carter, V. L. Richmond, S. D. Blacker, and M. P. Rayson. The effect of cool water ingestion on gastrointestinal pill temperature. *Med. Sci. Sports Exerc*., 40, 523–528, 2008.