Document Title: Soft Armor Effects on Core Body Temperature, Draft Final Summary Overview

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Soft Armor Effects on Core Body Temperature

Draft Final Summary Overview

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Purpose of the study

The role of body armor in preventing or reducing severe injuries in the law enforcement community has been well documented [4]. However, there is concern that lack of comfort, including increase in body temperature, may decrease the usage of armor. Previous research has been conducted on the effect of wearing body armor on core body temperature, however the primary focus has been on the military community. Additionally, many of the studies were "laboratory-based" where volunteer subjects were observed during various tasks or physically challenging maneuvers and not in the real world environment.

The development of temperature monitoring technology has allowed for the collection of core body temperature data in real-time in the field. The CorTemp Physiological Monitoring System (HQ, Inc) features an ingestible thermometer pill and a CorTemp ambulatory data recorder that delivers time-correlated core body temperature accurate to ± 0.1º C. It has been validated to accurately determine core body temperatures in a non-invasive, continuous monitoring manner. This is advantageous over the use of conventional types of core temperature monitoring devices such as rectal and esophageal probes. The use of such a system in the law enforcement environment allowed for officers to perform their duties in an unobstructed manner without the need for "simulating" the environment.

The purpose of this study was to examine the effects of agency-issued soft body armor on core temperature during real-world operations on core temperature. Data were collected during the normal activities of the law enforcement officer using the CorTemp system. These data were then examined based on ambient temperature, relative humidity, gender, age, and body mass index.

METHODS

Fifteen (15) law enforcement agencies and one (1) tactical medics training group were successfully recruited to participate in the study based on the unique characteristics of each agency. The agencies differed in geographical location, size, law enforcement capabilities as an agency, working environments, and issued uniforms and body armor. The participating agencies and location of each is represented in Table 1.

Table 1: Name and Location of Agencies Participating

Name of Agency	Location of Agency
El Paso Police Department	El Paso, TX
Colorado Springs Police Department	Colorado Springs, CO
Los Angeles Sheriff's Department	Los Angeles County, CA
Baton Rouge Police Department	Baton Rouge, LA
Hillsborough County Sheriff's Office	Hillsborough County, FL
Indian River County Sheriff's Office	Indian River County, FL
Tactical Medics International	Jacksonville, FL
Las Vegas Metro Police Department	Las Vegas, NV
Maricopa County Sheriff's Office	Maricopa County, AZ
Putnam County Sheriff's Office	Putnam County, FL
Cook County Sheriff's Office	Chicago, IL
Reynoldsburg Police Department	Reynoldsburg, OH
Libertyville Police Department	Libertyville, IL
Hocking County Sheriff's Office	Hocking County, OH
Glencoe Police Department	Glencoe, IL

Six (6) regions of the continental United States were identified: West Coast (1), Mountain West (2), Midwest (3), Northeast (4), Desert Southwest (5), and Southeast (6). Each region was represented by at least two (2) Law Enforcement Agencies in order to ensure data collection under a wide variety of environmental conditions (Figure 1).

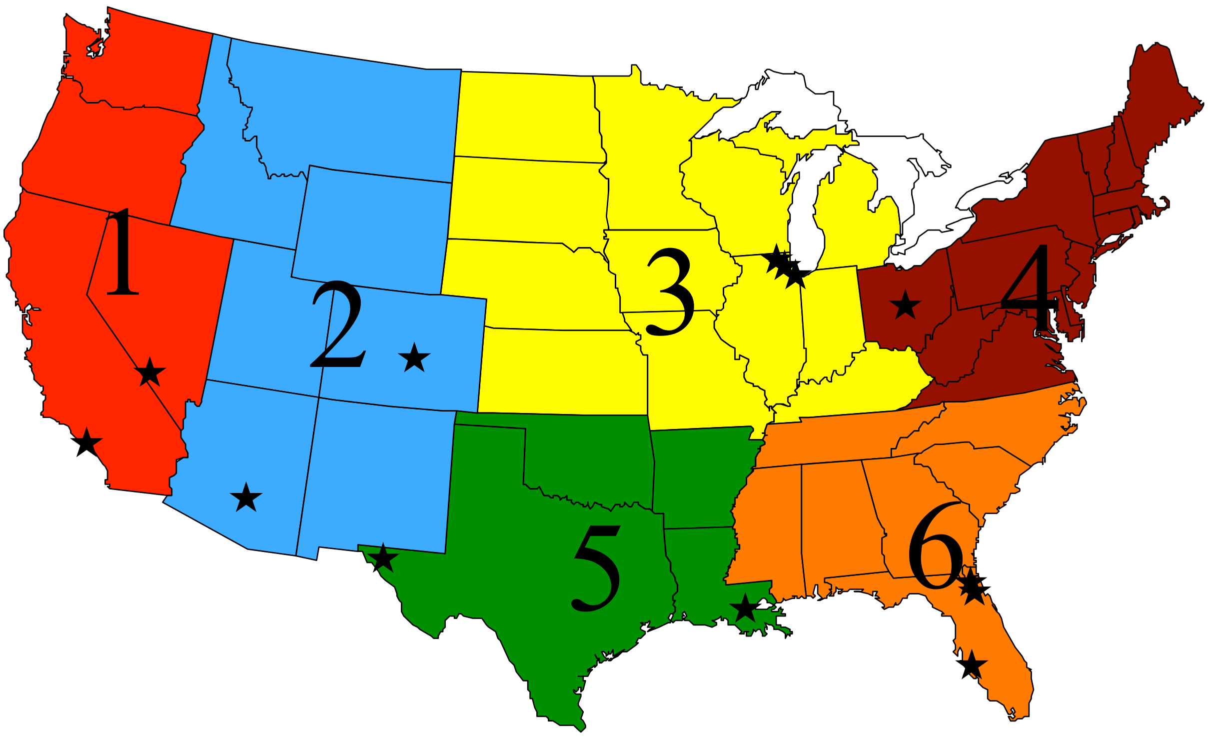

Figure 1: Geographical Regions and Locations of Agencies

A total of 504 volunteer subjects were consented. The average age for the consented participants was 38.36 ± 8.83 years. The majority of subjects were male (90.7%) with only 47 females participating. The average height was 69.96 inches with a range of 61 to 81 inches. The average mass of the subjects was 199.32 lbs (range: 115-310 lbs). Body mass index was also calculated for the subjects.

The subjects represented a variety of uniformed positions including: patrol, motor unit, bike unit, mounted unit, sniper and K-9 handler. Data were captured for those subjects wearing outer (overt) body armor carriers as well as the traditional "covert" body armor carriers. All practices conformed to the guidelines of the Wayne State University Human Investigation Committee, the University of Southern California Institutional Review Board, and all pertinent HIPPA regulations.

After the agency agreed to participate in the study, the researchers recruited individual subjects during the normal role call. Subjects provided written informed consent, and were advised of the purpose of a study. If they agreed to participate, they were instructed to work their normal shift as assigned. The subjects completed a brief questionnaire asking for their basic demographics and uniform dress. Subjects were instructed to dress, as they normally would, wear the body armor that they normally wear, perform duties as they normally perform, and maintain their hydration status as they normally would.

Each subject was asked to ingest a CorTemp Ingestible Core Body Temperature Sensor at the beginning of his/her shift. They were also provided information about the CorTemp body temperature sensor and data recorder. The CorTemp Sensor wirelessly transmitted core body temperatures to the recorder while in the subject's digestive tract. The CorTemp Data Recorder was worn on the subject's person (duty belt or higher). The recorder was programmed to collect at data point every ten (10) seconds and store it within the internal memory of the device. At the end of the shift the recorders were collected and the data transferred to a laptop computer.

The accuracy of the data was dependent on the core temperature transmitted passing into the intestines within the gastrointestinal system. This process varied for each subject; therefore the standardized processing of at least three (3) consecutive readings above 98.6 degrees was used to indicate the beginning of the data. Any deviation of more than .5 degrees in a subsequent value resulted in the subsequent value being eliminated. Data were then averaged over a fifteen (15) minute time duration to allow for additional analysis.

Historical weather data was extracted for each location based for the day on which the testing occurred. Both peak temperature and relative humidity was recorded.

RESULTS

The number of subjects recruited in each region can be found in Table 2. Although only approximately 5% of subjects were recruited from Region 4, this was not a concern because the environmental temperatures were not significantly elevated in this region.

Table 2: Number of subjects recruited in each region.

Geographic Region	Number of Subjects
REGION 1	86
REGION 2	96
REGION 3	70
REGION 4	24
REGION 5	124
REGION 6	104

The average temperature for the regions ranged from a low of 42 degrees in Region 4 to a high of 109 in Region 1 (See Figure 2). The relative humidity ranged from 66.73% (Region 2) to 99.20% (Region 4).

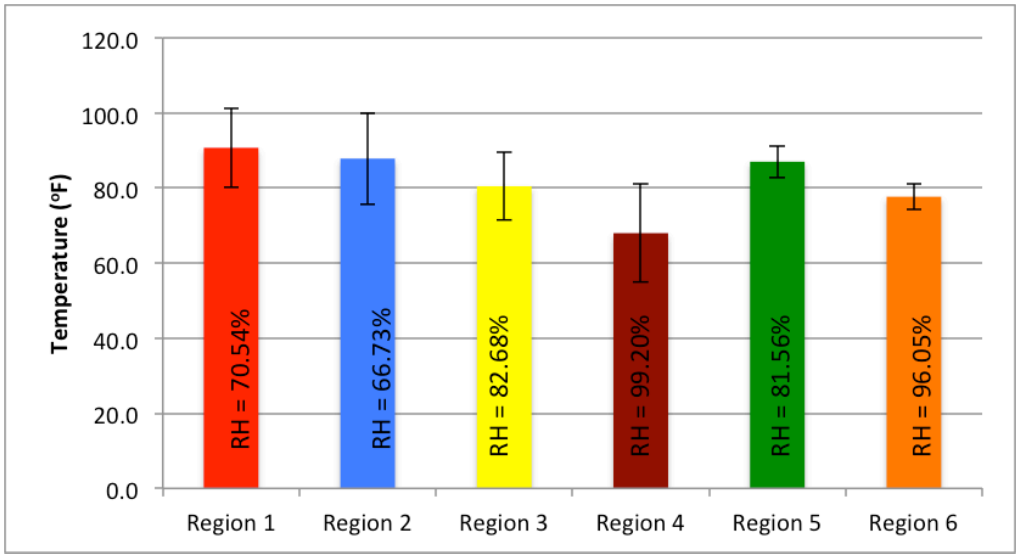

Figure 2: Average Ambient Temperature and Relative Humidity for Regions

The data collected was downloaded onto a laptop and was reviewed for accuracy. The typical output can be found in Figure 3. As seen in the figure, erroneous data as indicated by the "spikes" was collected throughout the time period and post-processing of the data was required. As previously described, the data was analyzed for outliers and then averaged over every fifteen minutes. Any files that did not produce viable results were eliminated. The maximum peak temperature and maximum average temperature for each time period was extracted and further analyzed.

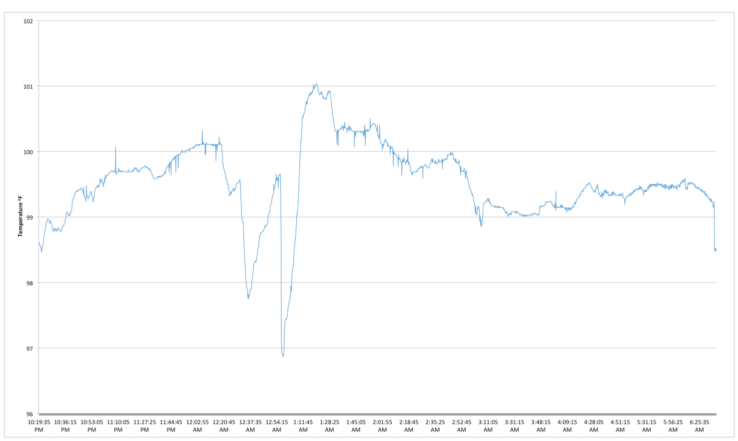

Figure 3: Typical output from CoreTemp system.

The final dataset analyzed included at total of 383 subjects with a mean peak temperature of 100.34 ± .83 °F. Subjects included in this dataset had a body mass index of 29.15 ± 4.18 kg/m^2. The mean peak temperature for each of the five regions ranged from 99.98 °F (Region 4) to 100.56 °F (Region 6).

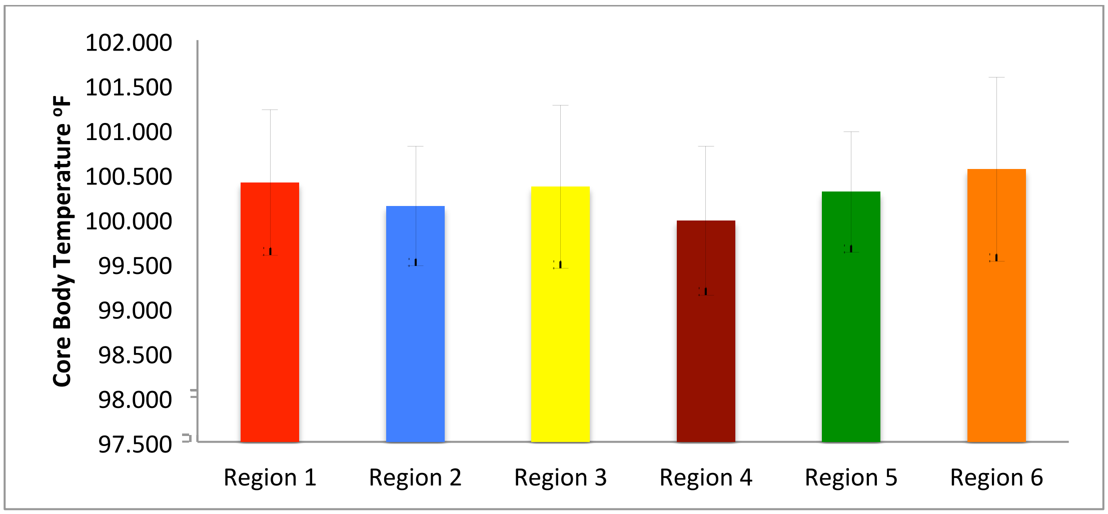

Figure 4: Mean Peak Core Body Temperature by Region

There were only seventeen (17) subjects in the dataset that were not wearing armor. This finding was as expected based on the fact that subjects were not requested to make any changes in their normal uniform dress. The mean peak temperature for these 17 subjects was 100.25 ± .75 °F. This was not significantly different from the mean peak temperature for those wearing armor (100.34 ± .83 °F). However, it was noted the maximum average peak temperature was 104.25 °F and 101.75 °F among those subjects wearing and not wearing armor, respectively.

Approximately 10% of the subjects were female. There was no significant difference between the male and female average peak temperatures (p=.260). Female subjects had an average peak temperature of 100.49 ± 1.01 ^{o}F while male subjects had an average peak temperature of 100.32 ± .81 ^{o}F.

The current study did not indicate that wearing body armor significantly increase core body temperature in various environmental conditions. There was no correlation found between ambient temperature, relative humidity, body mass index and core body temperature (Table 3 and Table 4). There was a trend for relative humidity to correlate with Core Temp (p=0.093), however it was not statistically significant. In addition, there was a correlation between ambient temperature and humidity, however this was not a focus of the study and was to be expected.

Table 3: Pearson Correlation Matrix

Variables	Air T	%RH	BMI	Core T
Air T	**1**	**-0.767**	0.042	-0.043
%RH	**-0.767**	**1**	-0.023	0.087
BMI	0.042	-0.023	**1**	-0.003
Core T	-0.043	0.087	-0.003	**1**

Table 4: p-values

Variables	Air T	%RH	BMI	Core T
Air T	**0**	**0.000**	0.428	0.400
%RH	**< 0.0001**	**0**	0.673	0.093
BMI	0.428	0.673	**0**	0.954
Core T	0.400	0.093	0.954	**0**

Even though the initial analysis showed no significant trends in the data, a more detailed analysis by region may be able to generate significant findings. Given the wide variability of subjects recruited, there may be some merit in analyzing specific subgroups of the data in the future.

Despite the lack of significant core body temperature increases, there may still be an overall physiological effect of wearing armor in extreme temperature conditions. Poor performance has been linked to increases in core body temperatures during training exercises [1]. In addition, increase oxygen consumption and ratings of perceived exertion have been reported [3]. These findings have predominately been reported in the military community where the tasks differ from those in the law enforcement community. In one study, specific to the law enforcement community, changes in cognitive strategy were noted in those wearing armor versus not [5].

Recently cooling devices have been suggested to decrease the heat effects of wearing armor. Several devices exist including those that use forced air and cooled water [2]. In addition, passive cooling interventions have been proposed such as spacer garments and reflective thermal inserts. The vast majority of these studies have been conducted in a laboratory setting with a specific population. It is unclear what effect, if any, these devices would have in the law enforcement community.

Scholarly Publications in Progress

Bir, CA and Kleiner, D. *Law Enforcement Officers, Ballistic Body Armor, and Core Body Temperature.* Accepted: IACP Annual Conference, October 2015.

Bir, CA and Kleiner, D. *The Effects of Body Armor on Core Body Temperature, and New Thoughts on Exertional Heat Illness.* Accepted: IACP Annual Conference, October 2015.

Bir, CA and Kleiner, D. *The Effects of Body Armor on Core Body Temperature in a Real-World Setting.* To be submitted: Ergonomics or Military Medicine

Implications for Criminal Justice

The practical implication of this project was to deliver valid data that describes the degree of heat stress as a result of wearing soft body armor. While just the first step in a series of steps that need to be taken, this initial project may have a significant impact on law enforcement practices. It is hoped that this project will lead to better understanding of the thermal load that accompanies body armor, and that such information will motivate body armor manufacturers to better design products that are lighter, cooler, and more comfortable.

Furthermore, policymakers and practitioners may also benefit from this proposed work beyond the scope of body armor improvements. It is hoped that more Law Enforcement Officers, and Law Enforcement Agency Trainers and Educators become better educated about heat stress and heat illnesses, even in the absence of body armor. Many recruits participating in physical training as part of their academy experience succumb to heat illnesses, which are potentially life-threatening. Better information on proper hydration, nutrition, and the importance of maintaining physical fitness throughout one's law enforcement career will help reduce morbidity and mortality, as well as the agency's liability posture and public image.

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