Evaluating Firefighters' hyperthermia level with CNT based cooling system during live burn firefighting-Preliminary findings

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WHAT HAVE we Learned from on-going Firefighter Project Since 2001

Physiological data collected:

1) Real-time **Heart Rate**
2) Real time **Core Body Temperature**
3) Real time changes in **Hyperthermia**

BACKGROUND

- **During Firefighting Core Body Temperature continues to rise above Hyperthermia level >38 C**

- **Firefighters' experience Core Body Temperature (CBT) levels above the hyperthermia limit i.e. 38 Celsius while fighting fire (Brake et. al 2002, Mani et. al 2013).**

- **Firefighters, experience above hyperthermia limit CBT levels even after ending the firefighting suggesting potential residual heat build up.**

- **On average 100 on-duty firefighter deaths occur every year in the United States. Forty-five percent of these deaths are cardiovascular (CV) related and are a major cause of morbidity**

Mani A, Musolin K, James K, Kincer G, Alexander B, Succop P, Lovett W, Jetter WA, Bhattacharya A, "Risk factors associated with live fire training: buildup of heat stress and fatigue, recovery and role of micro-breaks" Occupational Ergonomics Vol 11: (2013) 109–121 109; DOI 10.3233/OER-130212

MAGNITUDE OF RISKS FOR FIRE FIGHTERS

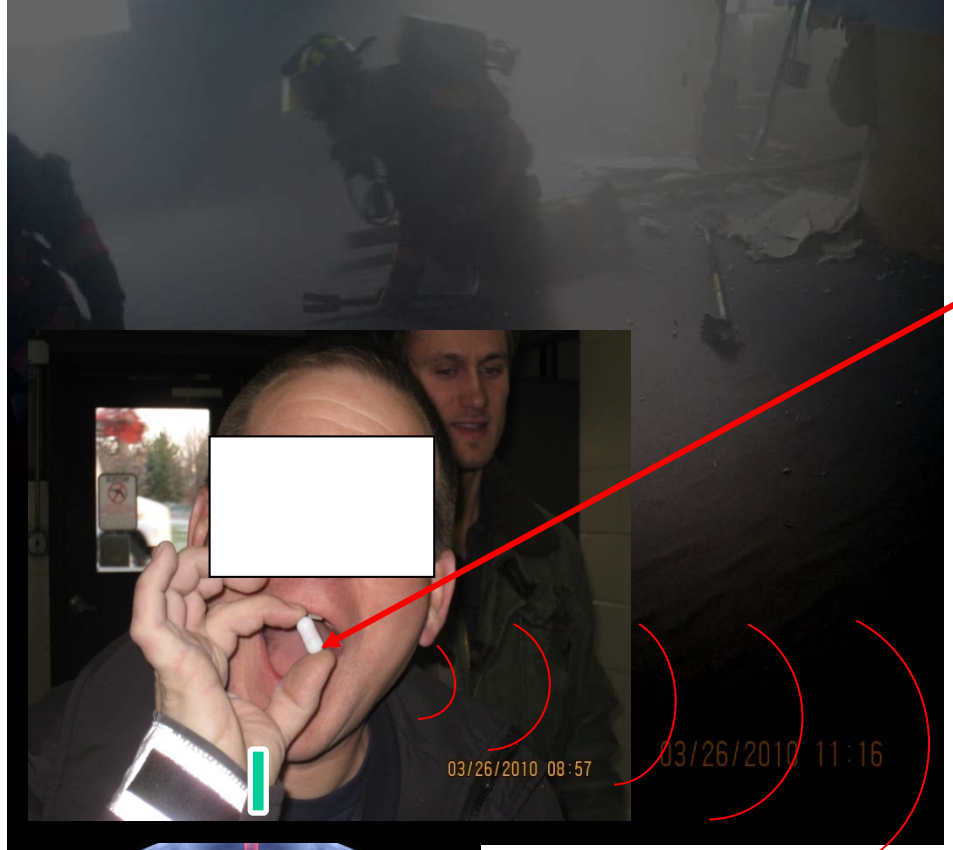
Firefighters are at high risk for sudden cardiac arrest; and one contributor is the **extreme cardiovascular strain** **due to the** **work demands and heat stress**

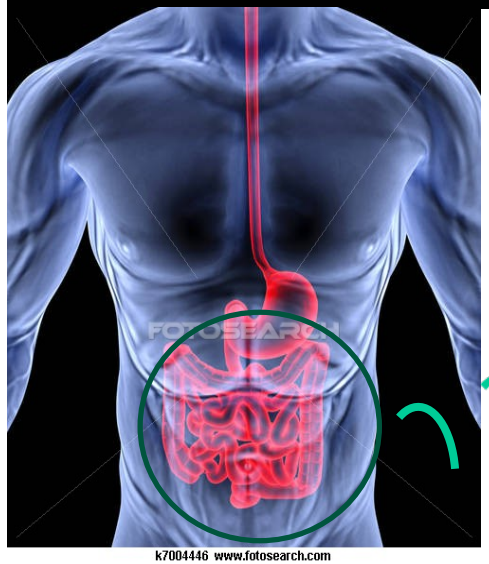
WARNING!

"Firefighters are at risk of dying on the job from preventable cardiovascular conditions"

Ref: NIOSH 2007-133

Ingestible Radio-Pill for measuring core body temperature

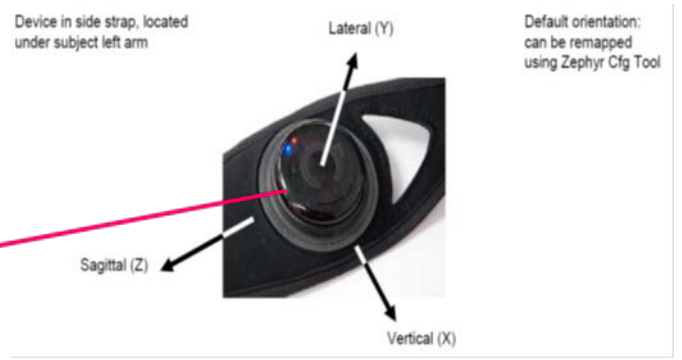




Wearable Inertial Link sensor-BIOHARNESS

BIOHARNESS Quantifies the effect of physically demanding tasks performed under hot environment

CORE BODY Temperature
Postural Balance
HR
ECG
Respiration



BIOHARNESS

K. James, Mani A, Kincer G and Bhattacharya A, "*Effects of Heat Stress on Firefighters' Postural Balance During Live Fire Fighting*" AIHce 2013, May 2013 at the Montreal Convention Center, Canada

Brief description of Active Textile (AT) system integrated into Firefighter Turnout Gear*

1. Carbon nanotubes are lightweight, flame resistant, and possess high mechanical and thermal properties.

2. Carbon nanotubes are also thermally anisotropic, meaning they easily conduct heat along the axis of an individual tube, and are relatively insulating across the tube's diameter.

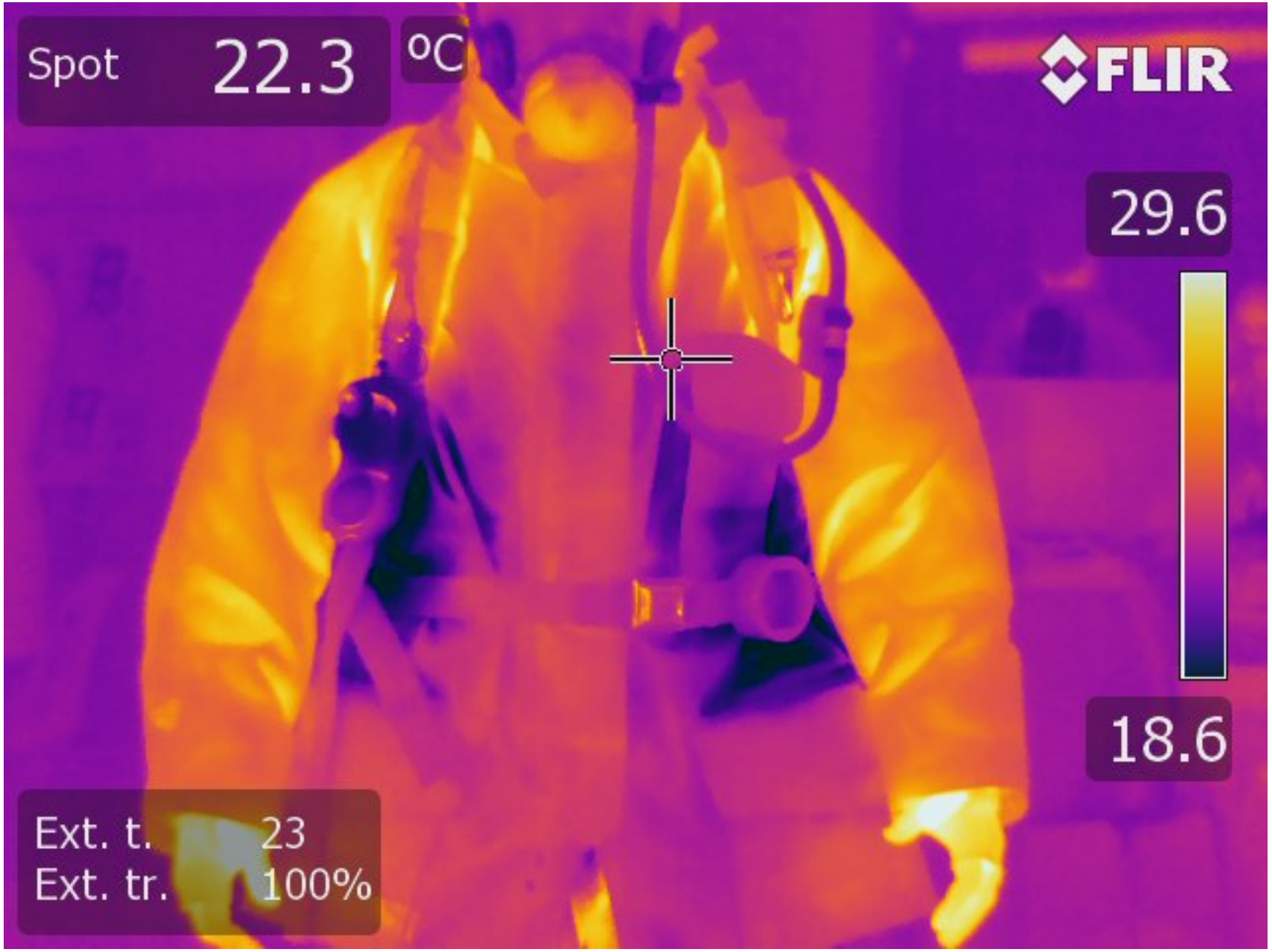
3. By recognizing this anisotropic behavior, heat transfer through a layer of aligned carbon nanotubes in a garment can be partially redirected to a cold reservoir thereby protecting the wearer from heat stress and exhaustion.

4. Simulation showed that under heat stress conditions, firefighter skin temperature was considerably reduced by the cooling layer.

FANS Circulate coolant air throughout the coat/body

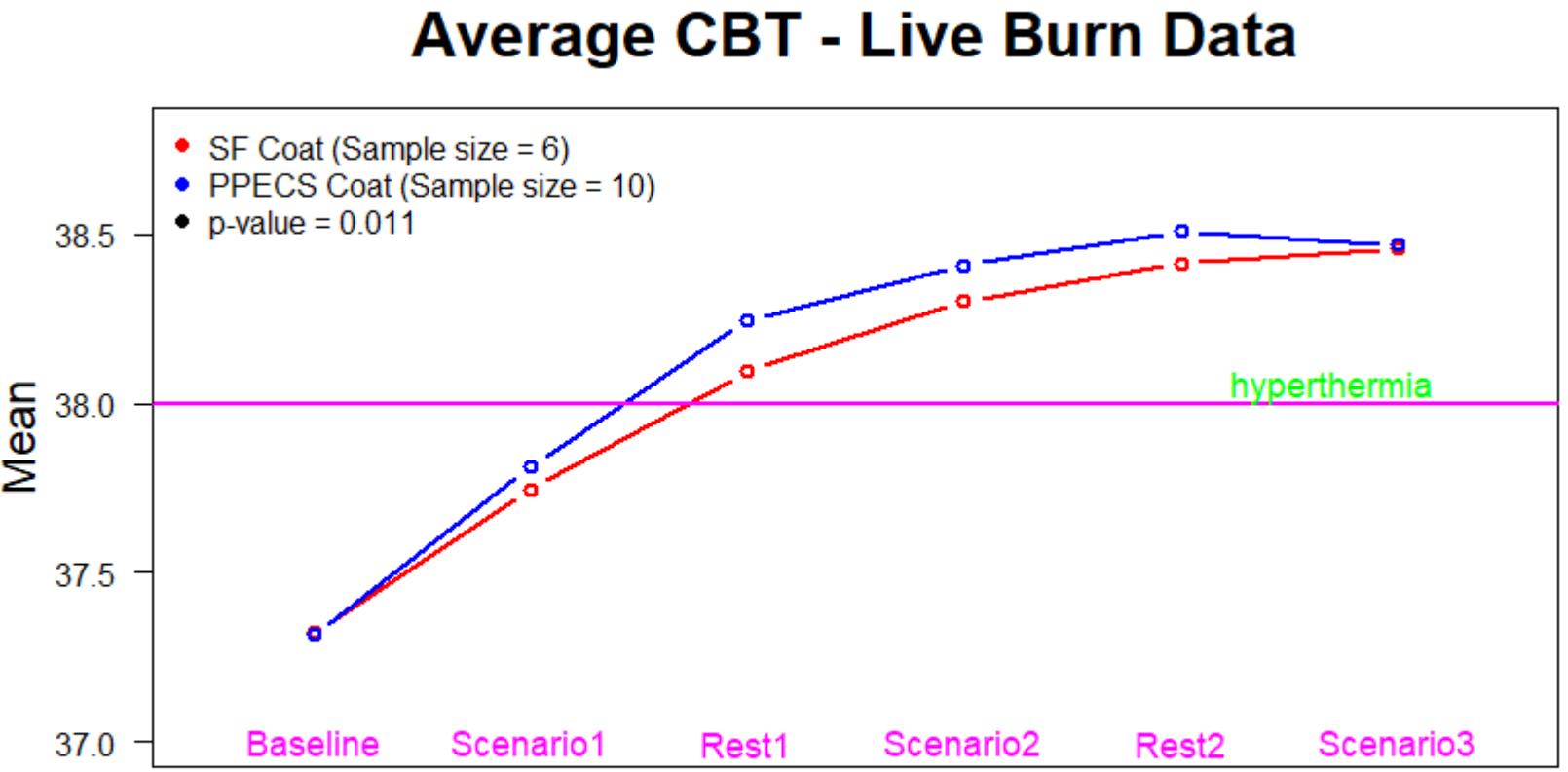
Cold Reservoirs-
Dry Ice

*J. Sullivan, M. Schulz, K. Vemaganti, A. Bhattacharya, B.J. Jetter, V. Shanov, N. Alvarez, Jay Kim; Carbon Nanotube Fabric Cooling System for Firefighters and First Responders: Modeling and Simulation, Journal of Fiber Bioengineering and Informatics 8 (1) 1–12, 2015.


Spot 22.3 °C
FLIR
29.6
18.6
Ext. t. 23
Ext. tr. 100%

Comparing CBT by coat – two-sample comparison

CBT	Baseline	Scenatio1	Rest1	Scenatio2	Rest2	Scenatio3
SF(n=6)	37.3	37.7	38.1	38.3	38.4	38.5
PPECS(n=10)	37.3	37.8	38.2	38.4	38.5	38.5



Comment:

- The CBT temperature during baseline and Scenario 1 was below hyperthermia level for both SF and CS coats.

- However, CBTs for both coats increased by 0.5 degrees above the hyperthermia level during Scenarios 2 and 3 suggesting need for additional coolant for the CS coats

Summary
CORE BODY TEMPERATURE AND HEART RATE OVER TIME WITH SF COAT

Comments:

- The core body temperature remains below 38℃ during the baseline and Scenario1.
- The average temperature remains above 38℃ persistently after Scenario1.
- The heart rate is exhibiting an expected pattern: high during the scenarios and low during rest period.

During Live Burn

Time dependent changes in core body temperature and heart rate
cs COAT

Comments:

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CONCLUSIONS

- **In general, the CS coat is better than the standard coat with respect to Thermal comfort and Respiratory distress Responses**

- **In the future, we will be modifying the cooling system to further enhance the Active Textile (AT) system's cooling capacity**