Exertional Heat Illness Prevention: A Military Perspective

Primary Care Approach to Treating the Injured Athlete

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DISCLOSURE

- I have no relevant financial disclosures in reference to this lecture.
- That being said, I am a physician in the US Army, and work for the DoD.

My opinions and assertions contained herein are private views and are not to be construed as official or as reflecting the views of the U.S. Army Medical Department, Uniformed Services University or the Department of Defense at large.
Objectives

- Discuss the epidemiology of exertional heat illness (EHI) in athletes and warriors.
- Review the definition and clinical description of EHI.
- Identify strategies utilized to facilitate acclimatization and prevent EHI.
Exertional Heat Illness: Epidemiology
Heat Stroke is Common in the Military!

- MSMR March 2014 21(3)

418 Exertional Heat Stroke Events in 2015!
Exertion-Related Injuries despite Prevention!

- The Medical Surveillance Monthly Report found over 12,700 cases of reported EHI and ER in between 2013 to 2017.
EHI Events Inversely Related to Race Duration

- Marathon (1-2 per 10,000 finishers Twin Cities Marathon)
- Half Marathon (1 per 1,000 finishers Great North Run)
- 7 Miler (2 per 1,000 finishers Falmouth Road Race)

EHI Events Directly Related to Heat Index

Cardiac Arrest or Heat Stroke?

- **METHODS:** retrospective study examined all the long distance popular races that took place in Tel Aviv from March 2007 to November 2013.

- **RESULTS:** Overall, 137,580 runners participated in long distance races during the study period. There were only 2 serious cardiac events (1 myocardial infarction and 1 hypotensive supraventricular tachyarrhythmia); there were 21 serious cases of heat stroke, including 2 that were fatal and 12 that were life threatening. **One of the heat stroke fatalities presented with cardiac arrest.**

- **CONCLUSIONS:** In our cohort of athletes participating in endurance sports, **for every serious cardiac adverse event, there were 10 serious events related to heat stroke.**

Exertional Heat Stroke in Football Players

- Since 1995, 54 reported football player fatalities from exertional heat stroke (42 high school, 9 college, 2 professional, 1 sandlot).

- Exertional heat illness (EHI) occurred at a rate of 1.20 per 100,000 athlete exposures (95% CI=1.12, 1.28).

- EHI were widely distributed geographically, and most occurred in August (60.3%); almost one third (32.0%) occurred more than 2 hours into the practice session.

- The EHI rate in football (4.42 per 100,000 AEs) was 11.4 times that in all other sports combined.

Exertional Heat Stroke is Arguably the Most Common Cause of Preventable Non-traumatic Exertional Sudden Death in American Sports

Why do Individuals Die from Heat Stoke?

• These **two items** were present in 100% of fatal cases
  
  • 1) Physical effort unmatched to physical fitness
  • 2) Absence of proper medical triage

Heat Illness: Definition

Terminology

- **Thermoregulation:**
  - Body heat is gained from the environment and is produced by metabolism
  - Heat dissipation ensues:
    - Vasodilation
    - Thermal sweating
    - Evaporation
    - Convection
    - Conduction
    - Radiation

An intact and functioning Cardiovascular System in Critical!
Terminology

- **Thermotolerance**: the ability to compensate to heat stress and sustain work; those individuals who are unable to sustain heat and whose body temperatures rise faster than others in comparable conditions are said to be heat intolerant.

<table>
<thead>
<tr>
<th>TABLE 2. Classification of factors underlying heat intolerance in the young active population.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Congenital</strong>: ectodermal dysplasia</td>
</tr>
<tr>
<td><strong>Functional</strong>: low physical fitness</td>
</tr>
<tr>
<td><strong>Acquired</strong>: sweat gland dysfunction</td>
</tr>
<tr>
<td><strong>Congenital</strong>: “chronic idiopathic anhidrosis”</td>
</tr>
<tr>
<td><strong>Functional</strong>: lack of acclimatization</td>
</tr>
<tr>
<td><strong>Acquired</strong>: dehydration</td>
</tr>
<tr>
<td><strong>Congenital</strong>: low work efficiency</td>
</tr>
<tr>
<td><strong>Acquired</strong>: infectious disease</td>
</tr>
<tr>
<td><strong>Congenital</strong>: reduced skin area to body mass ratio</td>
</tr>
<tr>
<td><strong>Acquired</strong>: x-ray irradiation</td>
</tr>
<tr>
<td><strong>Acquired</strong>: previous heat stroke (?)</td>
</tr>
<tr>
<td><strong>Acquired</strong>: large scarred burns skin area</td>
</tr>
<tr>
<td><strong>Acquired</strong>: drugs</td>
</tr>
</tbody>
</table>
**Acclimatization:**

- Takes several weeks to complete:
  - Activation of renin-angiotensin-aldosterone system
  - Salt conservation
  - Expansion of plasma volume
  - Increased ability to resist rhabdomyolysis
Definition

- **Heat Stroke**: a severe illness characterized by a core temp >40C and CNS abnormalities including delirium, convulsions, or coma.
  - **Classic**: resulting from environmental heat.
  - **Exertional**: resulting from strenuous exercise.

“A form of hyperthermia associated with a **systemic inflammatory response** leading to a syndrome of multiorgan dysfunction in which encephalopathy predominates.”
They Can Be Delirious!
Pathophysiology of Heat Stroke...Still a Mystery!

- **Exaggeration of the Acute-Phase Response**
  - Gastrointestinal tract may fuel inflammatory response
  - Ischemia with hyperpermeability
  - Leakage of endotoxins promotes systemic cytokine response to include pyrogenic cytokines

- **Thermoregulatory Failure**
  - Inadequate cardiac output

- **Alteration of the Heat-Shock Response**
  - Aging
  - Lack of acclimatization
  - Genetic predisposition
Clinical Manifestations

- Hyperthermia
  - 40 to 47°C
- CNS Dysfunction
  - Inappropriate behavior to coma
  - Cerebellar dysfunction with ataxia
  - Seizures may occur especially during cooling
Gabriella Anderson
1984 Los Angeles Olympics
Exertional Heat Illness: Prevention
Leavell’s Prevention Levels

- **Primary:**
  - Keeps disease process from becoming established by eliminating causes or increasing resistance.

- **Secondary:**
  - *Interrupts* or detects the disease *before it becomes symptomatic.*

- **Tertiary:**
  - Limits the consequences of symptomatic disease.
Risk Factors

- Age
- Poor physical fitness
- Lack of acclimatization
- Obesity
- Prolonged exertion
- Lack of sleep
- Illness
- Skin disease
- History of heat injury
- Drug use e.g. ephedra
- Use of heavy equipment or clothing

Obesity

- Obese and overweight men were 3.2 times more likely (p<0.01) to sustain any heat illness than non-obese men during the first 90 days of service.

Medications that Inhibit Thermoregulation

- Anticholinergics
- Antihistamines
- Tricyclics
- Stimulants
- Diuretics
- Antipsychotics
- ACE inhibitors,
- B-blockers
- Supplements
DMAA and Heat Stroke

- **Vasoconstrictor**
  - Inability to properly thermoregulate

- **Strain to Cardiovascular System**
  - Increased BP

- **Increased Metabolic Heat**
  - Increased cellular metabolism

- **Excessive Sense of Energy**
  - Loss of self governor to regulate activity
Heat Stress is Cumulative

- **PURPOSE:** To determine whether cumulative daily average wet-bulb globe temperature (WBGT) index, over one or two preceding days, is a better measure for predicting cases of exertional heat illness (EHI) than current daily average WBGT.

- **METHODS:** A case-crossover study was conducted in male and female Marine Corps recruits in basic training at Marine Corps Recruit Depot, Parris Island, SC.

- **RESULTS:** The risk of EHI increased with WBGT (OR = 1.11 degrees F(-1); 95% CI, 1.10-1.13). EHI risk was associated not only with the WBGT at the time of the event (OR = 1.10 degrees F(-1); 95% CI, 1.08-1.11) but with the previous day's average WBGT as well (OR = 1.03 degrees F(-1); 95% CI, 1.02-1.05).

- **CONCLUSION:** Our results provide evidence for a cumulative effect of PREVIOUS DAY'S HEAT EXPOSURE on EHI risk in these Marine recruits.

Primary Prevention

- Air Conditioning
- Acclimatization
- Hydration/Exertion Tables
- Modification of uniform/training sites
  - Remove headgear when not on field
- Increase spacing and positioning resting athletes in shade whenever possible
  - Consider tentage next to training areas
- Pre/Intra-Cooling

### Work/Rest and Water Consumption Table

<table>
<thead>
<tr>
<th>Heat Category</th>
<th>VDOT Index</th>
<th>Easy Work</th>
<th>Moderate Work</th>
<th>Hard Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Work (W)</td>
<td>Water (qt/hr)</td>
<td>Work (W)</td>
</tr>
<tr>
<td>High</td>
<td>60°F - 85°F</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>85°F - 95°F</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>&gt; 95°F</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

- Applies to average sized, heat-acclimated soldier wearing BDU, hot weather. (See TB MED 507 for further guidance.)
- The VDOT work times and fluid replacement volumes will sustain performance and hydration for at least 1 hr of work in the specified heat category. Fluid needs can vary based on individual differences (± 1 qt/hr) and exposure to full sun or full shade.
- "NR" = no limit to work time per hr.
- Rest = minimal physical activity including sitting or standing accomplished in shade if possible.
- CAUTION: Heavy fluid intake should not exceed 7.5 quarts. Daily fluid intake should not exceed 7.5 quarts.
- If wearing body armor, add 9°F to VDOT index in humid climates.
- If doing Easy Work and wearing NMC (C/W) or clothing, add 10°F to VDOT index.
- If doing Moderate or Hard Work and wearing NMC (C/W) or clothing, add 26°F to VDOT index.
Terminology

- **Acclimatization:**
  - Takes several weeks to complete:
    - Activation of renin-angiotensin-aldosterone system
    - Salt conservation
    - Expansion of plasma volume
    - Increased ability to resist rhabdomyolysis

Primary Prevention

- USARIEM
  - TB MED 507
# Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated soldier wearing BDU, hot weather. (See TB MED 507 for further guidance.)

<table>
<thead>
<tr>
<th>Easy Work</th>
<th>Moderate Work</th>
<th>Hard Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Weapon Maintenance</td>
<td>• Walking Loose Sand at 2.5 mph, No Load</td>
<td>• Walking Hard Surface at 3.5 mph, ≥ 40 lb Load</td>
</tr>
<tr>
<td>• Walking Hard Surface at 2.5 mph, &lt; 30 lb Load</td>
<td>• Walking Hard Surface at 3.5 mph, &lt; 40 lb Load</td>
<td>• Walking Loose Sand at 2.5 mph with Load</td>
</tr>
<tr>
<td>• Marksmanship Training</td>
<td>• Calisthenics</td>
<td>• Field Assaults</td>
</tr>
<tr>
<td>• Drill and Ceremony</td>
<td>• Patrolling</td>
<td></td>
</tr>
<tr>
<td>• Manual of Arms</td>
<td>• Individual Movement Techniques, i.e., Low Crawl</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Defensive Position Construction</td>
<td></td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>Heat Category</th>
<th>WBGT Index, °F</th>
<th>Easy Work</th>
<th>Moderate Work</th>
<th>Hard Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work/Rest (min)</td>
<td>Water Intake (qt/hr)</td>
<td>Work/Rest (min)</td>
<td>Water Intake (qt/hr)</td>
</tr>
<tr>
<td>1</td>
<td>78° - 81.9°</td>
<td>NL</td>
<td>1/2</td>
<td>40/20 min</td>
</tr>
<tr>
<td>2 (GREEN)</td>
<td>82° - 84.9°</td>
<td>NL</td>
<td>50/10 min</td>
<td>30/30 min</td>
</tr>
<tr>
<td>3 (YELLOW)</td>
<td>85° - 87.9°</td>
<td>NL</td>
<td>40/20 min</td>
<td>30/30 min</td>
</tr>
<tr>
<td>4 (RED)</td>
<td>88° - 89.9°</td>
<td>NL</td>
<td>30/30 min</td>
<td>20/40 min</td>
</tr>
<tr>
<td>5 (BLACK)</td>
<td>&gt; 90°</td>
<td>50/10 min</td>
<td>1</td>
<td>10/50 min</td>
</tr>
</tbody>
</table>

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hrs of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
- NL = no limit to work time per hr.
- Rest = minimal physical activity (sitting or standing) accomplished in shade if possible.

**CAUTION:** Hourly fluid intake should not exceed 1 ½ qts.

*Daily fluid intake should not exceed 12 qts.*

- If wearing body armor, add 5°F to WBGT index in humid climates.
- If doing Easy Work and wearing NBC (MOPP 4) clothing, add 10°F to WBGT index.
- If doing Moderate or Hard Work and wearing NBC (MOPP 4) clothing, add 20°F to WBGT index.

For additional copies, contact: U.S. Army Center for Health Promotion and Preventive Medicine Health Information Operations Division at (800) 222-9698 or CHPPM - Health Information Operations@apgea.army.mil.


June 2004
Most individuals can avoid fluid-balance problems by drinking when thirsty during and after exercise and eating a healthy diet. In healthy individuals, the thirst mechanism is

Key to this document is the Individualization of the Hydration Plan

If athletes do not know their individual sweat rates, drinking to thirst during activity most likely represents a safe strategy to prevent overdrinking. Drinking to thirst...
NATA Guideline on Acclimatization

- **Days 1 through 5** of the heat-acclimatization period consist of the first 5 days of formal practice. During this time, athletes may not participate in more than 1 practice per day.
- If a practice is interrupted by inclement weather or heat restrictions, the practice should recommence once conditions are deemed safe. Total practice time should not exceed 3 hours in any 1 day.
- A 1-hour maximum walk-through is permitted during days 1–5 of the heat-acclimatization period. However, a 3-hour recovery period should be inserted between the practice and walk-through (or vice versa).

Consensus Recommendations

- Acclimatization
- Hydration
- Cooling

Pre/Intr Event Cooling Strategies May Enhance Performance

CONCLUSIONS:

• Marathons in northern latitudes (>40 degrees) held in "unexpectedly" hot conditions when the participants are not acclimatized and the start WBGT is >21 degrees C often end in either race cancellation or an MCI.

• The rate of unsuccessful marathon starters per 1000 marathon finishers plotted against start WBGT generates a curve that can be used to estimate a do not start level.
Secondary Prevention

- Detection of milder forms of heat illness
  - Buddy System
- Use of those **sentinel cases** to modify training to prevent additional cases
- Screening for poor food and fluid intake
- Leveraging Heat Dumping
Secondary Prevention

- **Heat Dumping**
  - Encourage cool showers and time in air conditioning between high exertion training
  - If athletes are staying in dorms for summer training- check to ensure air conditioning is functioning
Tertiary Prevention

- **Tertiary prevention** efforts focus on people already affected by disease and attempt to reduce resultant disability and restore functionality.

- **Rapid cooling intervention** by first responders can reduce organ injury and prevent development of multi-organ dysfunction syndrome.
Time is Everything!!

“It’s a Heat Attack”

- **Goals:**
  - Increase the core to skin temperature gradient.
  - More effectively facilitate the transfer of heat from the core to the periphery to the external environment.
  - Decrease skin blood flow and facilitate an auto transfusion to the central circulation to decrease cardiovascular strain.
Field Treatment in 2018

- ABCs; rescue position; O2 4L NC
- Measure the patient's core temperature with a **rectal probe**
- Remove clothing and initiate external cooling
  - Cold packs to neck, axilla, groin
  - Continuous fanning
  - Ice water immersion
  - Facilitates an autotransfusion
- IV NS
- Treat on Site then Prepare for Transfer

It’s a Heat Attack!
IV. MCM HYPERTERMIA ALGORITHM

RECTAL TEMP ≥ 104°F // 40°C
LOSS OF THERMOREGULATORY CONTROL
EVIDENCE OF ACUTE ORGAN DYSFUNCTION
(Altered mental status / inappropriate behavior)

• RAPID EXTERNAL COOLING •
• IV NS 1-2 LITERS • (OBTAIN BLOOD CHEMISTRY SAMPLES •)
• CORE TEMPERATURE MONITORING (Q 3 MIN RECTAL TEMPERATURE OR INDWELLING RECTAL THERMISTOR)

• CONTINUOUS VITAL SIGN REASSESSMENT
• CONTINUOUS COOLING INTERVENTIONS

T ≤ 102°F - 102.5°F // 39°C

STOP COOLING TREATMENT
MONITOR FOR TEMPERATURE REBOUND
OR HYPOTHERMIC OVERSHOOT

PERSISTENT MENTAL OBTUNDATION

Y

SEVERE RHABDOMYOLYSIS EVIDENT •
NEED FOR ONGOING IV HYDRATION •

N

RELEASE WITH EXERCISE RESTRICTIONS &
PRECAUTIONS REGARDING RHABDOMYOLYSIS

ALL TEMPERATURES ARE RECTAL!

• RAPID COOLING OPTIONS: ICE WATER BATH IMMERSION, WHOLE BODY ICE MASSAGE/PACKING WITH CONTINUOUS ICE WATER DOUSING & OR ICE WATER-SOAKED SHEETS (REWETTED EVERY 3 MINUTES). FANS IF AVAILABLE. CONSIDER COOLED IV FLUIDS. STOP COOLING WHEN TEMPERATURE DROPS TO 102°F // 39°C OR BELOW.
• IVF: NS 2L BOLUS UNLESS SIGNS OF OVER-HYDRATION OR CHF (THEN NS @ KVO RATE); REASSESS ON-GOING IVF NEEDS FROM CLINICAL RESPONSE, URINE OUTPUT, AND LABS. COOLED FLUIDS FOR HEAT CASUALTY.
• IMMEDIATE Na, Gluc, K +/-, Cr, BUN, Cl & Hct (e.g. i-Stat®) TREAT HYPOGLYCEMIA AND HYPNATREMIA PER PROTOCOLS.
• IF RHABDOMYOLYSIS SUSPECTED, NEED CK, BMP, AST, ALT, LDH, Uric Acid & UA w/ Micro IF AVAILABLE.
  ADD Ca++, PO4, & Mg FOR SEVERE Rhabdo; IF NOT AVAILABLE, ALERT ER.
The Military Technique
Adjunctive Therapy

- Intravenous Chilled Saline
- Cold versus luke warm water
- Dantrolene
- Convection

Management in 2019

- Cooling
  - Immediate Cooling
- Supportive Therapy
  - Support of organ system function.
- Pursuit of therapies directed at causative mechanism of injury.

In 2019, Therapy Remains Largely Supportive!

Exertional Heat Illness: Prevention of Recurrence
When Can the Heat Stroke Patient Return to Play?

- Status of anatomical and functional healing;
- Status of recovery from acute illness and associated sequelae;
- Status of chronic injury or illness;
- Whether the athlete poses an undue risk to the safety of other participants;
- Restoration of sport-specific skills;
- Psychosocial readiness;
- Ability to perform safely with equipment modification, bracing, and orthoses;
- Compliance with applicable federal, state, local, school, and governing body regulations.

How Long Does it Take the Thermoregulatory System to Recover?

Is there a Risk of Returning an Athlete too Early?

What is the Risk of Recurrence?

- **METHODS:** Marine Corps members who completed at least 6 months of military service and suffered EHI treated as outpatients (N = 872) or inpatients (N = 50) during basic training (BT) in 1979-1991 at the Parris Island Marine Corps Recruit Depot, SC were compared to 1391 similar members (noncases). Subjects were followed from 6 months after accession into the military through the subsequent 4 yr.

- **RESULTS:** Military retention rates were slightly lower for those who suffered EHI during BT, compared with those who did not (24% vs 30% at 4 yr, respectively). Outpatient EHI cases also had about 40% higher subsequent hospitalization rates in military hospitals than noncases; differences declined over time and diagnoses showed little relationship to EHI. EHI cases had higher rates of hospitalization for EHI, but the number was too small (five hospitalizations) to provide comparisons.

- **CONCLUSION:** Hospitalization for EHI is uncommon during service after an initial episode during BT; occurrence of EHI during BT has only a small impact on subsequent military retention and hospitalization.

SPECIAL COMMUNICATIONS

Exertional Heat Illness during Training and Competition

This pronouncement was written for the American College of Sports Medicine by Lawrence E. Armstrong, Ph.D., FACSM (Chair); Douglas J. Casa, Ph.D., ATC, FACSM; Mindy Millard-Stafford, Ph.D., FACSM, Daniel S. Moran, Ph.D., FACSM; Scott W. Pyne, M.D., FACSM; and Wiliam O. Roberts, M.D., FACSM.

Five recommendations have been proposed for the return to training and competition (37).

1. Refrain from exercise for at least 7 d following release from medical care.
2. Follow up in about 1 wk for physical exam and repeat follow-up visits until exercise is cleared for competition in activities that present the greatest risk.
3. When cleared for activity, begin exercise in a cool environment and gradually increase the duration, intensity, and heat exposure for 2 wk to acclimatize.
4. A comprehensive history should be obtained post-incident (14,98,103,138).
5. Clear the athlete for full competition if heat tolerance exists after 2–4 wk of training.

How Do I really know if an Athlete is Heat Tolerant?

What’s a Heat Tolerance Test, and where do I get one?
CHAMP Workshop: Heat Illness: Return to Duty

- **Problem:** Line readiness affected by Warfighters on prolonged profile for heat illness; **no consensus and wide variation on return to duty.**
- **Solution:** Conference with DoD (OTSG) and American College of Sports Medicine on 22-23 October 2008 at USUHS to address returning to duty after heat injury
- **Deliverable:** Recommendations for new policy on return to duty for heat injury
- **Potential Outcome:** Evidence based return to duty; decreased health care costs.

A Paradigm Shift!

- Heat Stroke is an Event:
- Diagnosis is often Best Made Retrospectively and Individual Morbidity Determines Return!
Heat Stroke Return to Duty: A Retrospective Assessment

- **Heat Stroke Profile Determination:**
  - Following an episode of HS the affected Soldier(s) will be placed on a [T4 (P)] profile for a period of two weeks. For the purpose of further profile and MEB determination, the Soldier will be reassessed weekly for the presence or absence of both complications and contributing risk factor(s). The Soldier will then be classified into one of the following three categories:
    - **HS without sequelae:** all clinical signs and symptoms resolved by two weeks following the event;
    - **HS with sequelae:** any evidence of cognitive or behavioral dysfunction, renal impairment, hepatic dysfunction, rhabdomyolysis, or other related pathology that does not completely resolve by two weeks following the event;
    - **Complex HS:** recurrent, or occurring in the presence of a non-modifiable risk factor, either known (e.g. chronic skin condition such as eczema or burn skin graft) or suspected (e.g. sickle cell trait, malignant hyperthermia susceptibility).
  
- Profile Disposition of Soldiers with HS. See Table 1
The Heat Tolerance Test

The Heller Institute HTT protocol

Target population
- Suspected for heat susceptibility
- Cases of EHS or heat exhaustion (6-8 weeks after recovery)
- The test is limited to the ages 17-30 yrs.

Preliminary investigation
- Complete medical history (including family history about heat susceptibility)
- Medical check-up (preclude any illness)

Preliminary instructions (prior to the test)
- At least 6 hrs night sleep
- Normal diet
- Euhydration (not over hydrated)
- No physical exercise 48 hrs prior to the test

The Heat Tolerance Test: An Efficient Screening Tool for Evaluating Susceptibility to Heat

Daniel S. Moran, Tomer Erlich, and Yoram Epstein

© 2007 Human Kinetics, Inc.
Heat Intolerance Criteria

- **Primary measurements**
  - Rectal temperature $> 38.5^\circ C$
  - No plateau in the dynamics of rectal temperature

- **Supportive measurements**
  - HR $> 150$ bpm
  - Subjective feeling
  - Physiological indexes (Physiological Strain Index - PSI and Cumulative Heat Stress Index - CHSI)
Example: Heat Tolerant

Core temperature & skin temp during HTT

- $T_{core} < 38.5^\circ C$
- $\Delta T_{core} @ hr2 < 0.45^\circ C$

Heart rate (bpm) during HTT

- $HR < 150$ bpm
- Visual plateau
Example: Heat Intolerant

Core temperature & skin temp during HTT

- $T_{core} > 38.5\, ^{\circ}C$
- $\Delta T_{core, hr2} > 0.45\, ^{\circ}C$
- $T_{core} > 38.5\, ^{\circ}C$
- No visual plateau

Heart rate (bpm) during HTT

- $HR > 150\, bpm$
Returning Warfighters to Duty

HEAT TOLERANCE TEST RESULTS

Patient Information
Patient Name: [Redacted]
Date of Birth: [Redacted]
Age: 28

Diagnosis and Exclusion Information
Name of Diagnosis: Heat Tolerance Test
Date of Test: 10/01/2009
Time test was taken: 19:00
Location of Test: Environmental Chamber, Building 15, USUHS
Environmental conditions: Ambient temp: 45.5°C, Humidity: 40%
Procedures: Test performed: CPT, French O'Connor, M.D., Jennifer Davis, M.S.

Additional Information:

Test Patient Condition
Condition 1
Blood Pressure (MMHG): 118/75
Weight: 190.2 kg
Height: 190.2 cm
Body surface area (BSA): 2.4 m^2

Test Patient Condition
Condition 2
Hemoglobin (Hgb): 13.6 g/dL
Weight: 190.2 kg
Sweat rate: 0.52 kg/hr

Additional Information:

Exercise Tolerance Test Information
Exercise duration: 150 min
Type of Exercise: Rigid Treadmill, Cost Temp Full
Speed: 3.1 mph
Grade: 2.0%
Metabolic rate: 19.2 kcal/kg/min
Fluid intake: 7975 ml.

Table 1: Heat Stress Tolerance Test

<table>
<thead>
<tr>
<th>Condition</th>
<th>T0 (°C)</th>
<th>T1 (°C)</th>
<th>T2 (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>35.4</td>
<td>35.1</td>
<td>35.8</td>
</tr>
<tr>
<td>Test 1</td>
<td>36.4</td>
<td>36.1</td>
<td>36.8</td>
</tr>
<tr>
<td>Test 2</td>
<td>37.0</td>
<td>36.7</td>
<td>37.5</td>
</tr>
</tbody>
</table>

Note: Reference values for a resistant test. Heat stress = 50°C, core temperature = 38.0°C, sweat rate = 1.0 L/hr, and no adverse symptoms observed.
Unexplained Heat Stroke: Is There a Link?

What about the Brain?

- **Neurocognitive Testing**
  - Baseline assessments of neurocognitive status may be available
    - ANAM
    - Impact
- Project being developed at Fort Bragg, North Carolina
For further information please contact:

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