Heat Stress Management in 2020
13 October 2020

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Acknowledgments

University of South Florida
  • Candi D. Ashley
  • College of Public Health

NIOSH
  • Sunshine Education and Research Center
  • USF, UCF, and Embry-Riddle Aeronautical University
  • All NIOSH-Supported Centers
  • Research Awards

Other sponsors of my research and practice in heat stress
ACGIH® Physical Agents Committee
ISO Thermal Environments Working Group (ISO TC159 SC5 WG1)

These thoughts are really just my own. For some of these ideas, you should carry them into practice with professional judgment and caution.

Four Astonishing Things about Heat Stress

Heat Stress Assessment

Risk associated with exposures above the occupational exposure limit

Acclimatization Practices

Importance of monitoring signs and symptoms and taking appropriate actions
Heat Stress Assessment
--- Background on Standard Stuff ---

Wet Bulb Globe Temperature (WBGT)
Predicted Heat Strain (PHS)

WBGT-Based Exposure Limits
Premise
Performance
Congressional Charge to NIOSH

Recommend limits that include, but are not limited to, the exposures at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. (pg 11)

Note: “... diminished ... functional capacity”
- Basis for heat stress limits
- NIOSH Criteria Document for Occupational Exposure to Heat and Hot Environments (DHHS (NIOSH) Publication No. 2016-106)

Lind’s Observation (1963)


Upper Limit of the Prescriptive Zone: Transition from Work-Driven to Environment-Driven Core Temperature
Three Other Studies by Lind

1. Reinforced the ULPZ as an OEL with 100 participants
2. Demonstrated the limit works for both continuous and intermittent work
3. Up to the ULPZ, age does not affect the recommendation

Exposures from Kuhlemeier, et al.

<table>
<thead>
<tr>
<th>WBGT [°C]</th>
<th>M [W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>25</td>
<td>300</td>
</tr>
<tr>
<td>30</td>
<td>400</td>
</tr>
<tr>
<td>35</td>
<td>500</td>
</tr>
</tbody>
</table>

- >ULPZ
- <ULPZ
- TLV
What about Unacclimatized

At a moderate/high rate of work (350 W), the difference is about 2 - 3 °C-WBGT.
  • USF revisit of Kuhlemeier data suggests 3 °C difference

Professional Judgment by NIOSH Investigators
  • Less of a difference at lower work demands
  • Greater difference at higher work demands

WBGT Exposure Limit
(NIOSH, ACGIH® and ISO)
Revisited by USF

Ximena P. Garzón (Republic of Ecuador) and Candi Ashly

Exposure-Response Curve for Sustainable Exposures

Clear loss of thermal regulation with increase in rectal temperature greater than 1 °C/h at Sustainable + 3 °C-WBGT
Sensitivity and Specificity Among Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lind</td>
<td>0.95</td>
<td>0.69</td>
</tr>
<tr>
<td>Kuhlemeier</td>
<td>1.00</td>
<td>0.81</td>
</tr>
<tr>
<td>USF Progressive Heat Stress Studies</td>
<td>1.00</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Conclusions

REL / TLV
- High Sensitivity
- Very Low Specificity
  - High Rate of False Positives

A concern with face validity due to low specificity and baseline experience of about 20 to 200 cases per 100,000 FTE during summer months ...

... but the odds for being unsustainable become progressively higher with increasing heat stress (Odds Ratio between 2 and 2.5 / °C-WBGT).
Predicted Heat Strain

ISO7933 (current working group discussions)

Predicted Heat Strain

Rational Method for Heat Stress Assessment
  • Uses heat balance approach
  • Limits based on predicted rectal temperature and predicted sweat loss

Job Risk Factors
  • Environment
  • Metabolic rate
  • Clothing (standard validated with woven fabrics but applicable to nonwovens)
  • Time
PHS Implementations

ISO 7933

- Major change from 2004 edition and some small changes from 2017 draft

USF prepared an Excel® function call of 2017 version to assess laboratory exposures

What do we ask of the PHS Black Box?

Is an exposure safe? Yes / No

How long can an exposure safely last?
Summary of Results for Sustainable Exposures

<table>
<thead>
<tr>
<th>Clothing</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woven Clothing</td>
<td>1.00</td>
<td>0.18</td>
</tr>
<tr>
<td>Particle Barrier</td>
<td>0.95</td>
<td>0.60</td>
</tr>
<tr>
<td>Water Barrier</td>
<td>0.91</td>
<td>0.83</td>
</tr>
<tr>
<td>Vapor Barrier</td>
<td>0.91</td>
<td>0.80</td>
</tr>
<tr>
<td>All Clothing</td>
<td>0.94</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Unsustainable Exposures: Predicted $T_{re}$ at USF
Time Limit for Woven Clothing by Fixed Individual Factors
Predicted $T_{re}$ at USF Time Limit
All Clothing by Fixed Individual Factors

Risk Assessment

--- Novel Suggestions ---

Sustainable Heat Stress Exposures
Excessive Heat Stress Exposures
Time-Limited Exposures
Starting Point: Acceptable

When is the risk for unsustainable heat stress small for most healthy workers?

Baseline assumptions
- Moderate work (300 Watts)
- Ordinary work clothes
- Healthy worker
- Unacclimatized

REL / TLV minus 3 °C-WBGT or 25 °C-WBGT

Risk
- 1% probability of being an unsustainable exposure for a healthy unacclimatized worker.
- OSHA citations for heat stress start above this point

Next Step: Caution

When is the risk for unsustainable heat stress small for most healthy acclimatized workers?

Baseline
- Moderate work (300 W), Ordinary work clothes, Healthy worker
- Acclimatized

REL / TLV or 28 °C-WBGT

Risk
- 1% probability of being an unsustainable exposure for a healthy acclimatized worker
- About 10% probability of being an unsustainable exposure for unacclimatized
- About 1% probability of being an excessive exposure for unacclimatized
- Worker compensation claims for heat-related disorders start to increase by this limit
And Next Step: Moderate

When are the risks for excessive heat stress small for most healthy workers?
- Rectal temperature increasing by 1 °C / h

REL / TLV plus 3 °C-WBGT or 31 °C-WBGT
Note: This would be about a 30 / 30 work and recovery cycle

Risk
- 10% probability of being an unsustainable exposure for a healthy acclimatized worker
- 1% probability of being an excessive exposure for a healthy acclimatized worker
- About 50% probability of being an unsustainable exposure for unacclimatized
- About 10% probability of being an excessive exposure for unacclimatized

Finally: High

When are the risks for excessive heat stress significant for most healthy workers?

REL / TLV plus 6 °C-WBGT or 34 °C-WBGT
Note: this is the limit for resting only

Risk
- 50% probability of being an unsustainable exposure for a healthy acclimatized worker
- 10% probability of being an excessive exposure for a healthy acclimatized worker
- About 90% probability of being an unsustainable exposure for unacclimatized
- About 50% probability of being an excessive exposure for unacclimatized
Summarized in a Table

<table>
<thead>
<tr>
<th>Heat Stress Level</th>
<th>WBGT [°C]</th>
<th>Risk Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable</td>
<td>&lt; 25</td>
<td>• &lt; 1% probability unsustainable exposure for unacclimatized</td>
</tr>
<tr>
<td>Caution</td>
<td>25 to 28</td>
<td>• Up to 1% probability unsustainable exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 10% unsustainable exposure for unacclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 1% excessive exposure for unacclimatized</td>
</tr>
<tr>
<td>Moderate</td>
<td>28 to 31</td>
<td>• Up to 10% probability unsustainable exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to 1% probability excessive exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 10% probability unsustainable exposure for unacclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 1% excessive exposure for unacclimatized</td>
</tr>
<tr>
<td>High</td>
<td>31 to 34</td>
<td>• Up to 50% probability unsustainable exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to 10% probability excessive exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 90% probability unsustainable exposure for unacclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Up to about 50% probability excessive exposure for unacclimatized</td>
</tr>
<tr>
<td>Extremely High</td>
<td>&gt; 34</td>
<td>• &gt; 50% probability unsustainable exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• &gt; 10% probability excessive exposure for acclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• &gt; 90% probability unsustainable exposure for unacclimatized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• &gt; 50% probability excessive exposure for unacclimatized</td>
</tr>
</tbody>
</table>

Moderate work, ordinary clothing

Heat Index Alternative

National Weather Service (NWS) in the National Oceanic and Atmospheric Administration (NOAA) developed and promotes the Heat Index

NWS describes ranges of risk with a color code
- This has received scrutiny and should be used with caution

Crosswalk with WBGT [°C]
- HI [°F] = 0.24 WBGT² − 9.3 WBGT + 170
- Increase in HI for direct sun: 6 °F
  - For a limit value, decrease HI by 6 °F to add direct sun
Summarized in a Table

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable</td>
<td>&lt; 25</td>
<td>&lt; 84</td>
<td>&lt; 80 / 85*</td>
</tr>
<tr>
<td>Caution</td>
<td>25 to 28</td>
<td>84 to 94</td>
<td>&lt; 91</td>
</tr>
<tr>
<td>Moderate</td>
<td>28 to 31</td>
<td>94 to 106</td>
<td>91 to 103</td>
</tr>
<tr>
<td>High</td>
<td>31 to 34</td>
<td>106 to 130</td>
<td>103 to 115</td>
</tr>
<tr>
<td>Extremely High</td>
<td>&gt; 34</td>
<td>&gt; 130</td>
<td>&lt; 115</td>
</tr>
</tbody>
</table>

Moderate work, ordinary clothing, direct sun

* OSHA Studies

And a Heat Index Chart

Moderate work in the sun with regular clothing
In the PHS Domain

Acceptable
• If the time limit is not exceeded AND the predicted time limit is > 30 min

Room for professional judgment (Gray Area)
• A steady-state is established slightly above the threshold (e.g., 38.1 v 38.0)
• See exposure response curve for some insight into increasing risk combined with predicted rate of rise

Unacceptable
• Time limit is < 30 min

Assumption of Risk

The concept of assumption of risk is a work in progress for me.

Risk Inherent to the WBGT Occupational Exposure Limit
• Sustainable exposures versus heat-related disorders or outcomes
• Based on healthy individuals
• Perhaps aggressive acclimatization assumptions (4 days)

Other Accepted Risk
• Accepted risk inherent in individual heat stress management practices
Obligations for Assumption of Risk

When there is an acceptance of risk, there is an obligation to minimize the deleterious outcomes.

Obligations

• Policy on self-determination with active engagement of supervision
• Conservative (low threshold) recognition of heat-related disorders; especially, exertional heat illness. With the early recognition comes an appropriate response.
• Buddy system

Policy on Self-Determination

Self-limitation is a hygiene practice

There should be a stated policy that encourages workers to break when they think that they should

• There is a natural tendency to keep up with coworkers and to show supervision that they are team players
• Work incentives discourage breaks
• Supervisors should actively ask if individual workers would like a break
Acclimatization Practices

--- Beware of Nuances ---

Improvement in Heat Stress Tolerance

Physiological Adjustments
- Earlier onset of sweating
- Higher rate of sweat production for evaporative cooling
- Better electrolyte management

Benefits
- Lower cardiovascular strain
- Lower body core temperature
Imputed Importance

Unequivocal improvement in heat tolerance

Case Reports and OSHA Citations: Cases often occur in the first few days and there is an absence of a formal acclimatization program

- Unanswered question is the relative contribution of acclimatization state plus informal acclimatization versus personal and situational risk factors
- My Answer: Low tolerance to heat stress due to unknown combination of acclimatization state, informal program, personal risk factors and employment conditions (see distribution of medical review guidance)

Acclimatization Schedule

<table>
<thead>
<tr>
<th>Day</th>
<th>New</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>2</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>3</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>4</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

New is appropriate to high skill jobs.
Re-Acclimatization Schedule

<table>
<thead>
<tr>
<th>Routine Absence</th>
<th>Illness</th>
<th>Exposure Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>&lt; 4</td>
<td>—</td>
<td>100%</td>
</tr>
<tr>
<td>4 – 5</td>
<td>1 – 3</td>
<td>R/E†</td>
</tr>
<tr>
<td>6 – 12</td>
<td>4 – 5</td>
<td>80%</td>
</tr>
<tr>
<td>12 – 20</td>
<td>6 – 8</td>
<td>60%</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>&gt; 8</td>
<td>50%</td>
</tr>
</tbody>
</table>

† Reduce expectations, some loss of capacity

Acclimatization

Acclimatization vis-à-vis WBGT OEL
- 90% of unacclimatized healthy workers should exhibit a sustainable exposure at the OEL
- It is hard to know who is unacclimatized in contrast to who is not acclimatized

Acclimatization protocols are often well above the OEL (28 °C at 300 W)
- Hot, dry (50 °C, 20%rh): WBGT = 36 °C
  - At USF, we see most participants can achieve and sustain acceptable exposures for 2 h
- Less hot and dry (40 °C, 30%rh): WBGT = 30 °C
  - At USF, most participants demonstrated sustainable exposures from start
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Acclimatization Policy

The Action Limit / Recommended Alert Limit is less a threshold limit for unacclimatized workers (the rationale for the limit values) and more a trigger point.

Acclimatization is a managed transition from the AL / RAL to the OEL.

Policy

- Less reliance on fixed schedules
- Make allowances for acclimatization of new or returning workers
- Again, requires active supervision and employee participation

Recognition of and First Aid for Exertional Heat-Related Disorders

--- Discussion on Decisions for Clinical Treatment Continue ---
--- See Distribution of EHI Response Guide ---
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Backstop on Managing Risk

When everything else fails ...

Heat Stroke

**Signs**
- Severe Fatigue or Nausea/Vomiting – Watch for other signs of heat stroke while starting treatment for severe heat exhaustion.
- *You may see one or more of the following*
  - Erratic / Irritable Behavior
  - Confusion / Disorientation
  - Garbled / Gibberish Speech
  - Hysteria / Delirium / Apathy
  - Collapse
  - Shivering
  - Convulsions or Unconscious

**Actions**

*Emergency Response*
- Begin aggressive cooling (cover in ice or place in cold/ice water bath). If ice is not available, other methods of cooling are flushing water over person from hose or shower; or keep the skin wet and fanning.
- Call emergency services and advise them that it is a heat stroke case.
- Note: You need to know where you are
# Severe Heat Exhaustion

**Signs and Symptoms**

You may see one or more of the following:

- Wobbly Walking
- Slow Reaction Times
- Severe Fatigue
- Severe Muscle Cramps
- Vomiting or Collapse without Any Signs of Heat Stroke

*Person may say they have*

- Severe Fatigue
- Loss of Appetite
- Nausea
- Headache
- Blurred Vision

**Actions**

- Move to air-conditioned space, encourage water/electrolyte drink if able, and allow to lay down.

- Cover head and shoulders with a towel soaked in ice water.

- Watch for signs of heat stroke.

- If there is little improvement in 15 min, arrange for medical treatment and continue to watch for possible heat stroke.

# Mild Heat Exhaustion

**Symptoms**

*Person may say they feel*

- Tired / Fatigued
- Thirsty
- Weak
- Dizzy
- Lightheaded
- Faintness with change in posture or prolonged standing
- Muscle cramps

**Actions**

- Inform supervisor

- Recovery in cool area

- Drink water and/or electrolyte drink

*Note: If symptoms persist after 15 min, treat as severe heat exhaustion*
Other Heat-Related Disorders

Heat Syncope: Fainting or near-fainting experience with prolonged static postures or rapid change to an upright posture.

Heat Cramps: Painful spasms of abdominal or fatigued muscles.

Heat Rash: Small itchy rashes due to infected/blocked sweat glands.

Notes on Recognition and Treatment

Act early and error to the side of thinking there is a problem where none exists.

Heat stroke management depends on early recognition of signs. The person will not come up to you and say they have a heat stroke.

Any time a worker experiences a fainting spell or other form of collapse, medical approval for return to work is advised.
Thank you

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Sunshine Education and Research Center

Making a Difference