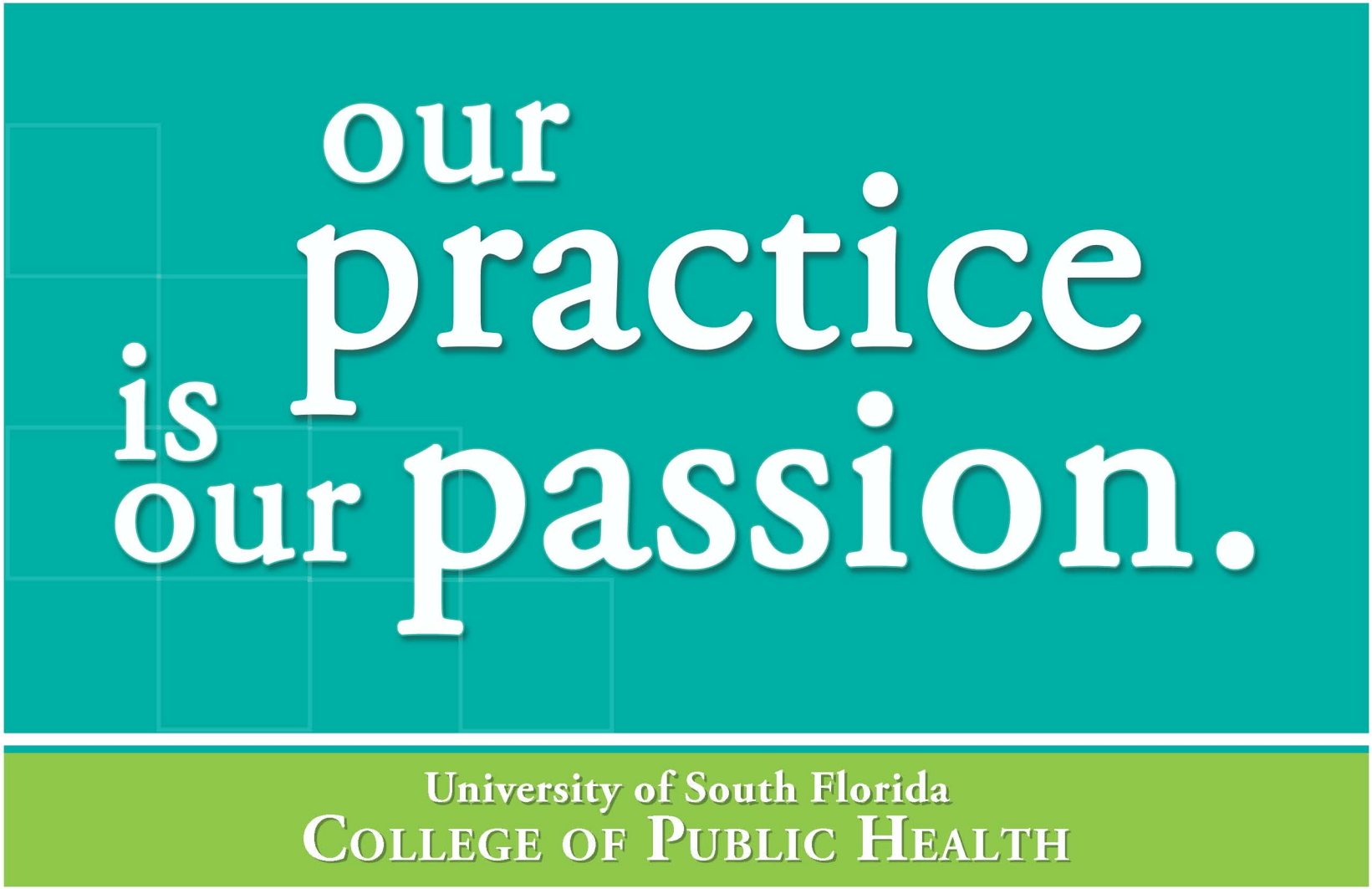
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Occupational Heat Stress Exposure Assessment: Limits on Sustainable Exposures

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Sunshine ERC
Education and Research Center
at the University of South Florida

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There are no conflicts of interest to report.
And I speak for nobody; my opinions are mine.

Case for Heat Stress as an Occupational Hazard

The case is clear that occupational heat stress as a cause of exertional heat illness;.

- Florida (2005-2012): 8.5 ED visits, 1.1 hospitalizations, and 0.1 deaths per 100,000 worker-years (~3 deaths/y)
- And there is a carry-over effect from the previous day(s)

There is also good evidence for heat stress as a contributor to acute injury/accidents.

Some evidence for heat stress as a contributor to productivity loss.

Bernard speculates that heat stress contributes to absenteeism and quality loss

Standards of Professional Practice

NIOSH criteria document for occupational heat stress (2016)

ACGIH® TLV ® for heat stress and strain (2018)

ISO 7243: Ergonomics of the Thermal Environment – WBGT (2017)

Occupational Exposure Limit

Development and Validation

Congressional Charge under OSH Act

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. [2(b)(7)]

Note: "… diminished … functional capacity"

- Basis for occupational heat stress limits
  - Sustainable (thermal balance) for 8 h
- Not Directly Considered
  - Physiological (heat) strain
  - Health and safety outcomes
  - Cognitive or psychomotor decrements

Job Risk Factors

Environment

- Wet Bulb Globe Temperature Index (WBGT) is an adequate analog for dry heat exchange and maximum evaporative cooling.
- Heat Index for outdoor work

Metabolic Rate

- May be largest source of error in heat stress assessment

Clothing

- Effects on maximum evaporative cooling

Classic Studies by Lind and His Associates

1. Established the Upper Limit of the Prescriptive Zone (ULPZ) for a sustainable exposure to heat stress as a function of metabolic rate and environment (1963)
   - General location and shape of the OEL
2. Confirmed the ULPZ at one metabolic rate with 3-hour exposures (1970)
   - Sustained nature of the OEL
   - Core temperature limit of 38°C not supported (perhaps 39°C)
   - Clouds WHO TRS 412 (1969) with regard to 38°C v. 39°C
   - Bernard & Kenney (1994): 38.5°C to allow time to get to recovery area
3. Demonstrated that ULPZ can apply to continuous and intermittent work for 8 hours (1963)
   - Sustained nature of the OEL
   - Time-Weighted Averaging
4. Demonstrated that ULPZ is independent of age (27 v 47 yo) (1970)

What about Unacclimatized?

Lind: Difference of 2 - 3°C-WBGT.

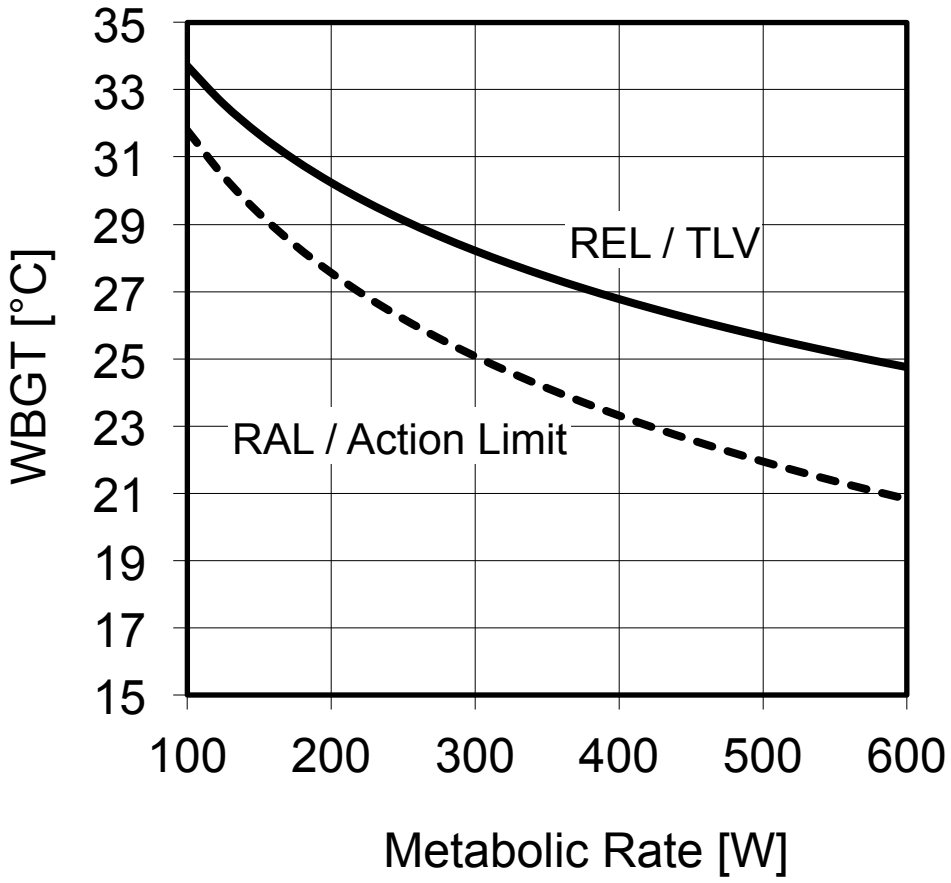
- Lind Unacclimatized at 350 W (28.4 and 27.4) v. Acclimatized (29.2)
- Wyndom (reported by Lind): 29.2 v. 31.9

NIOSH's Professional Judgment

- Less of a difference at lower work demands
- Greater difference at higher work demands

Bernard from Kuhlemeier Data: 3°C Difference

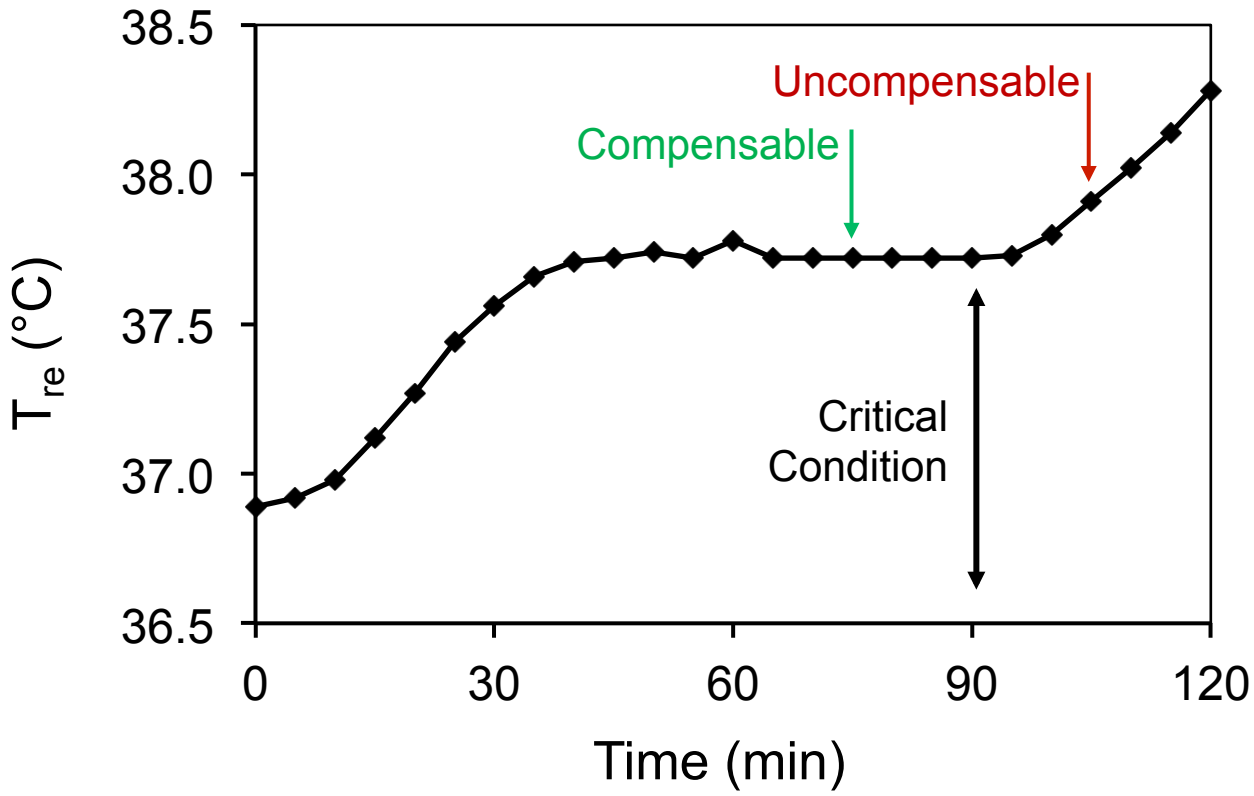
Occupational Exposure Limit
(NIOSH REL and RAL / ACGIH® TLV® and Action Limit)



USF Data

OEL (REL and TLV) Validation

Progressive Heat Stress Trial



Case Cross-over Design
Number of Pairs = 176

Metric: Elevation Above TLV

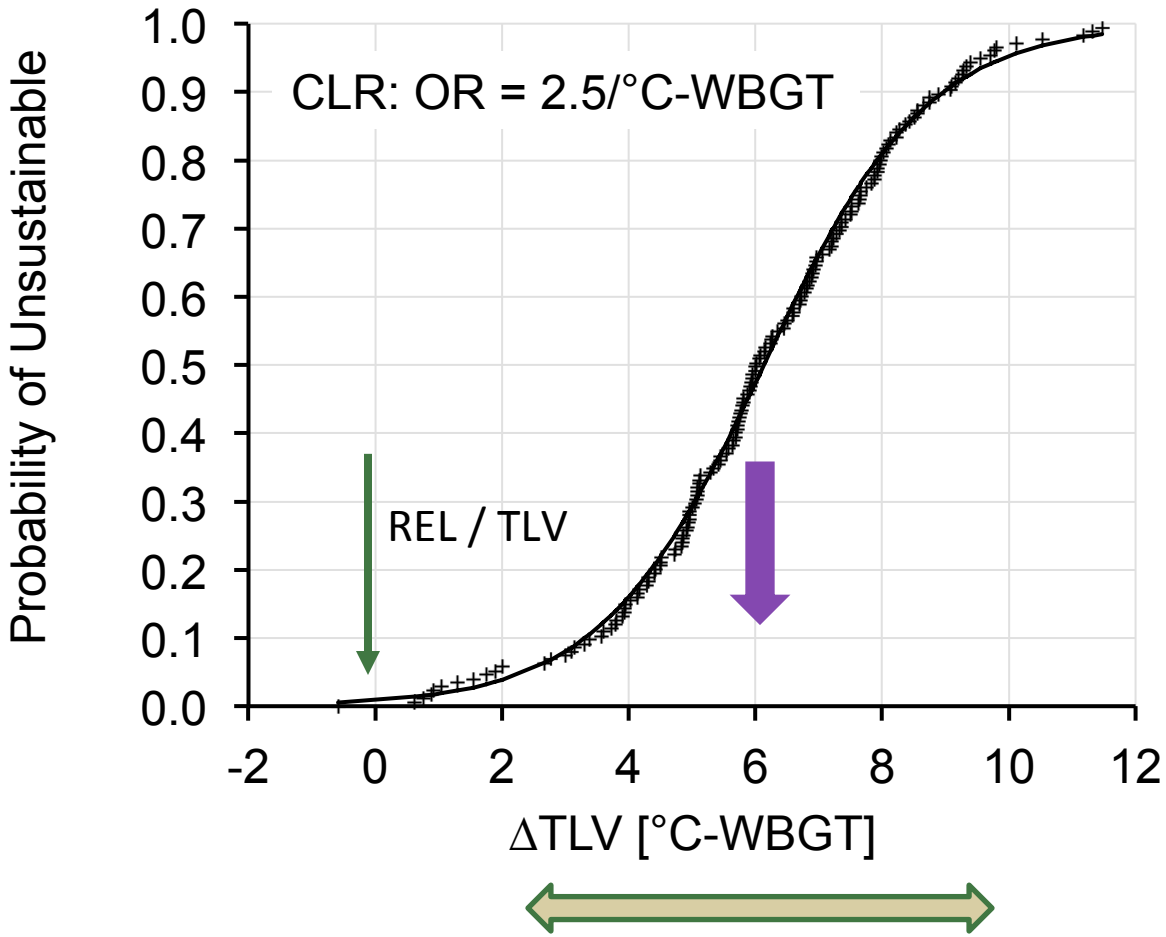
$\Delta TLV = WBGT_{observed} - TLV$

- TLV [°C-WBGT] = $56.7 - \log_{10}(M[W])$

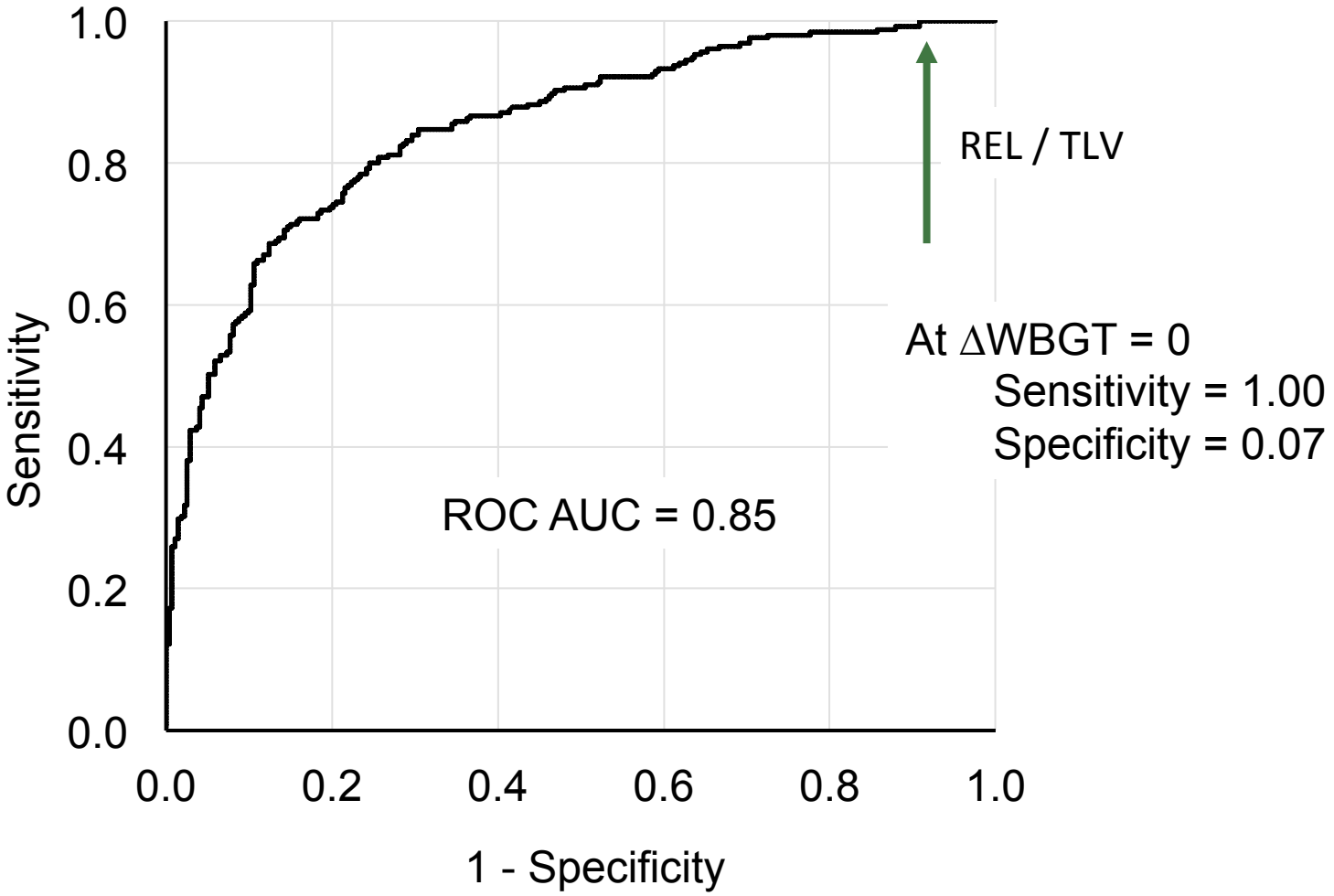
Experimental Design

- Five Clothing Ensembles
- Nested Design
  - Three Levels of Relative Humidity
  - Three Levels of Metabolic Rate

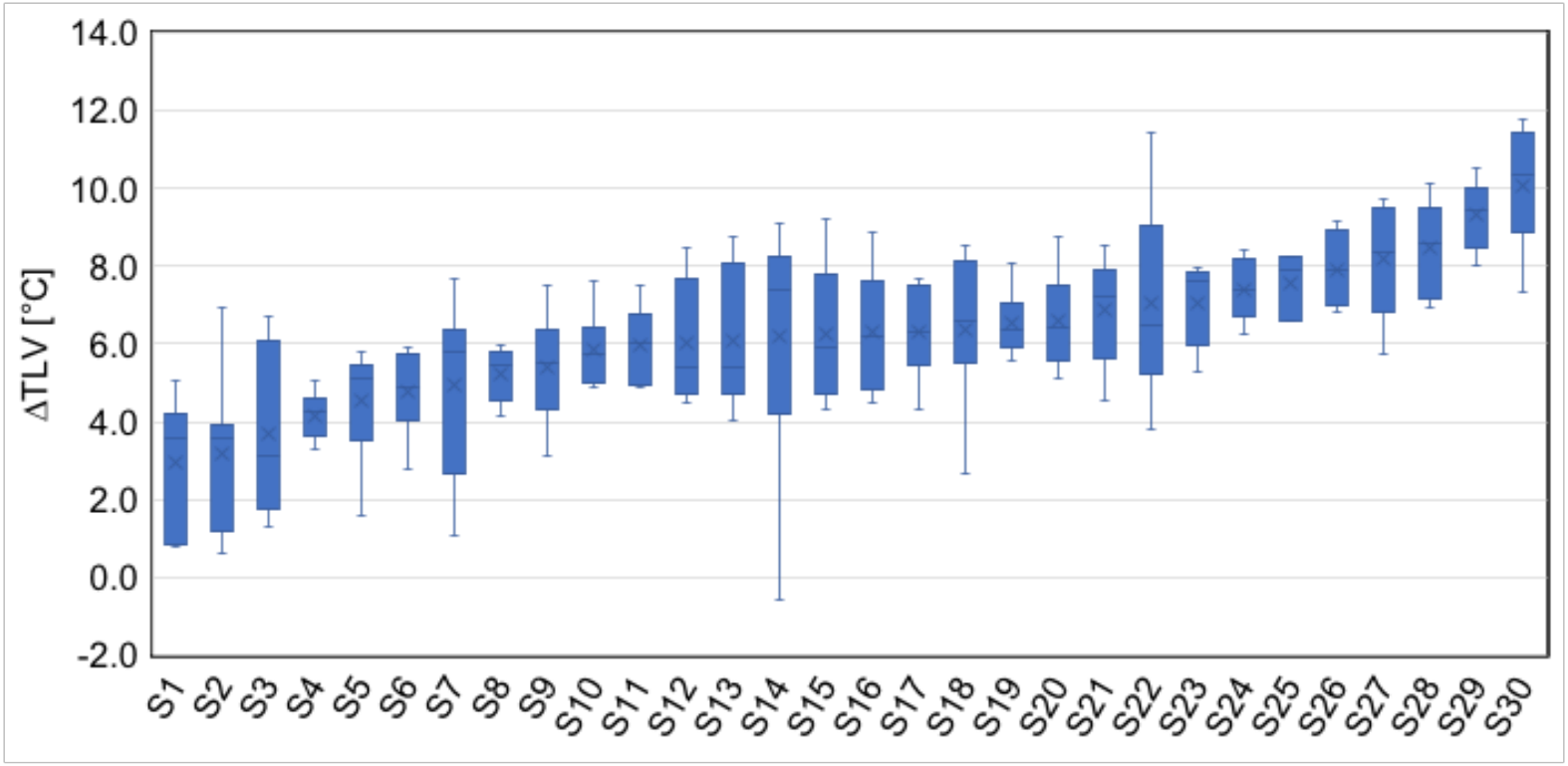
Exposure-Response Curve for Standard Clothing



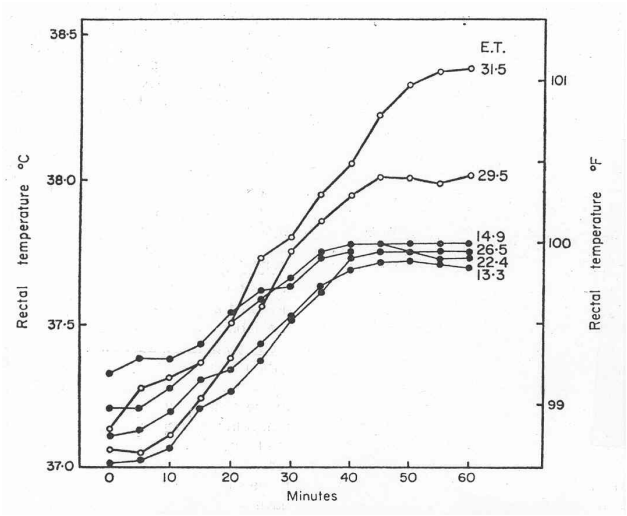
Receiver Operating Characteristic (ROC)



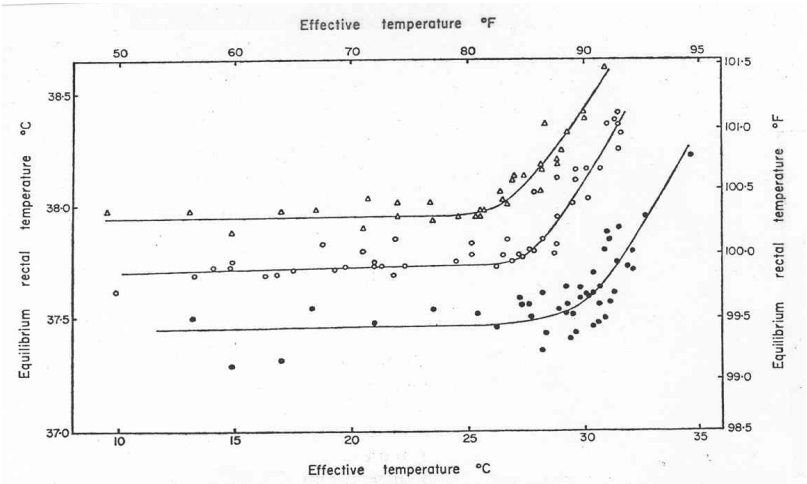
Inter- and Intra-Individual Variation for Standard Clothing

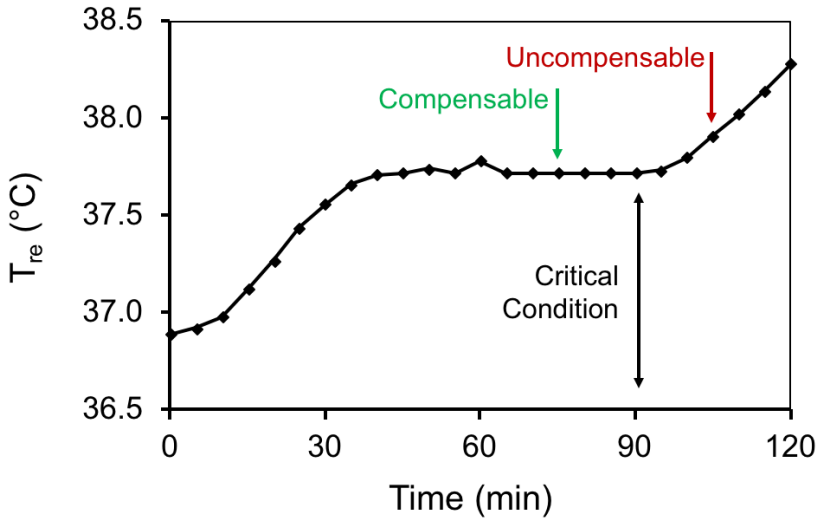


And …

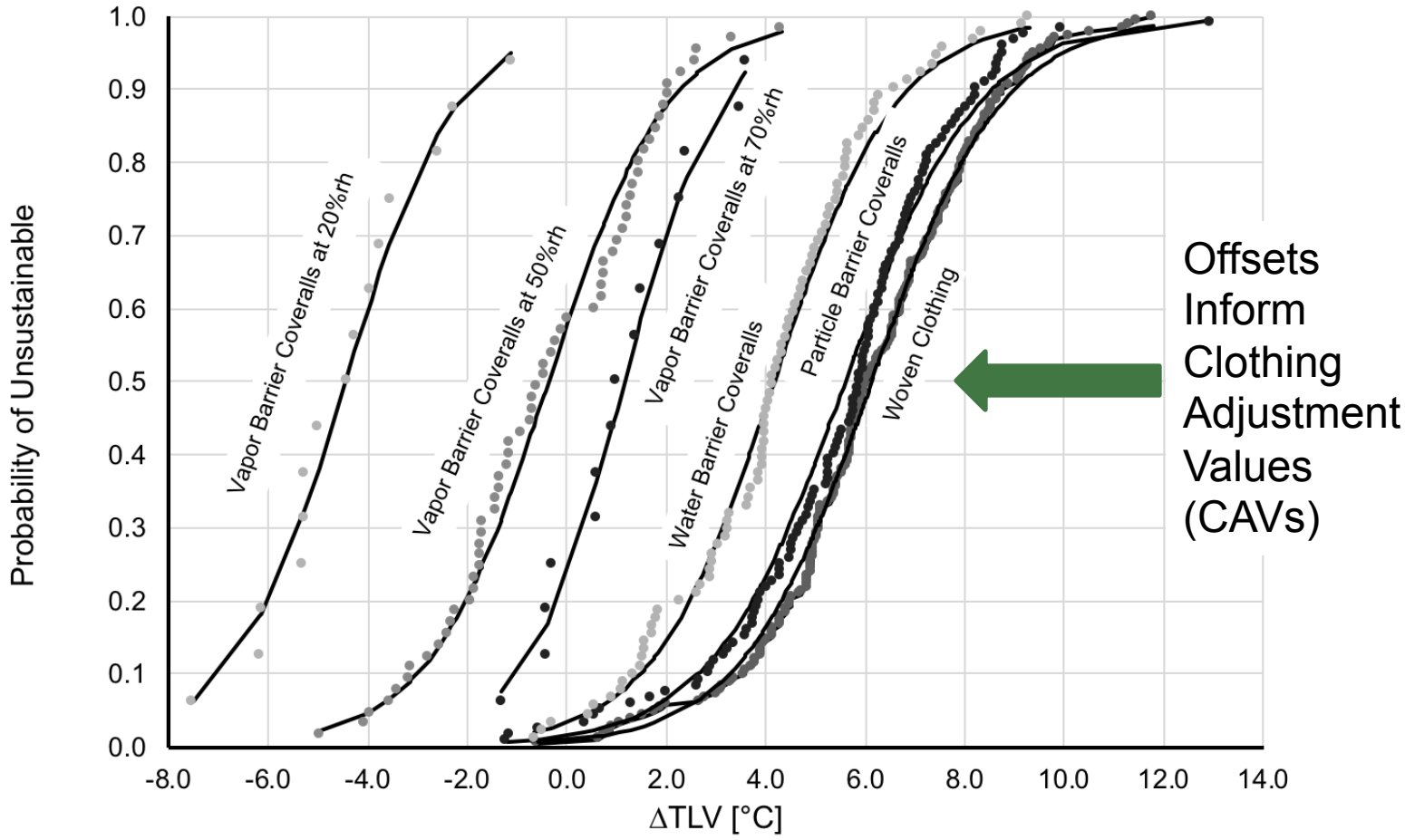


… above the ULPZ or Critical Condition, small changes in environment lead to rapid increases in the rate of heat storage



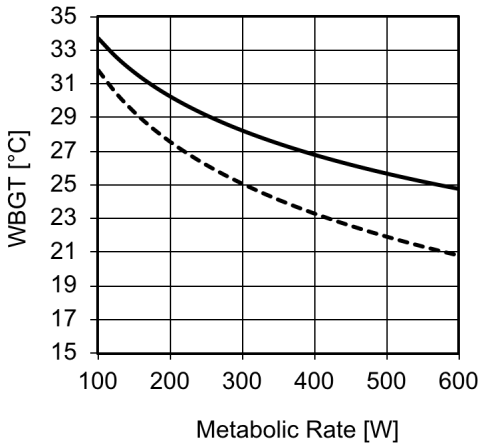


Exposure-Response Curves for Clothing



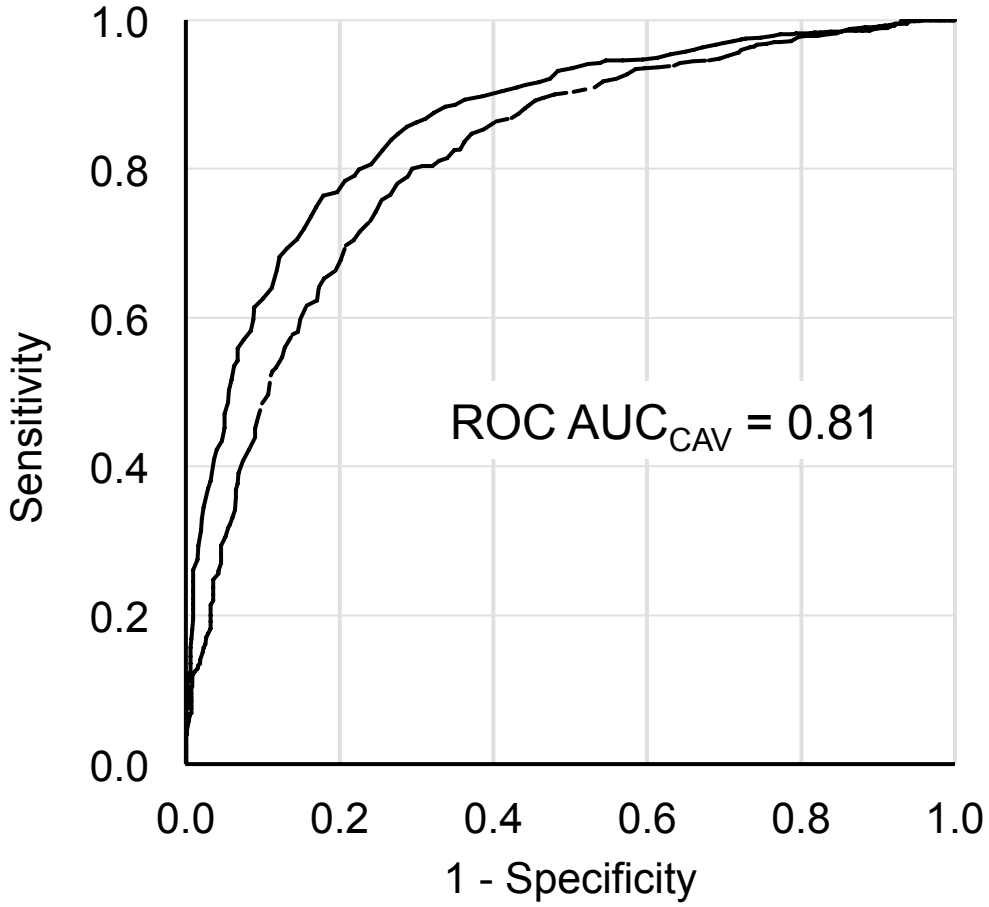
Effective WBGT

$$WBGT_{ambient} + \text{Clothing Adjustment Value} = WBGT_{eff}$$



Receiver Operating Characteristic (ROC)

Four Clothing Ensembles as CAV



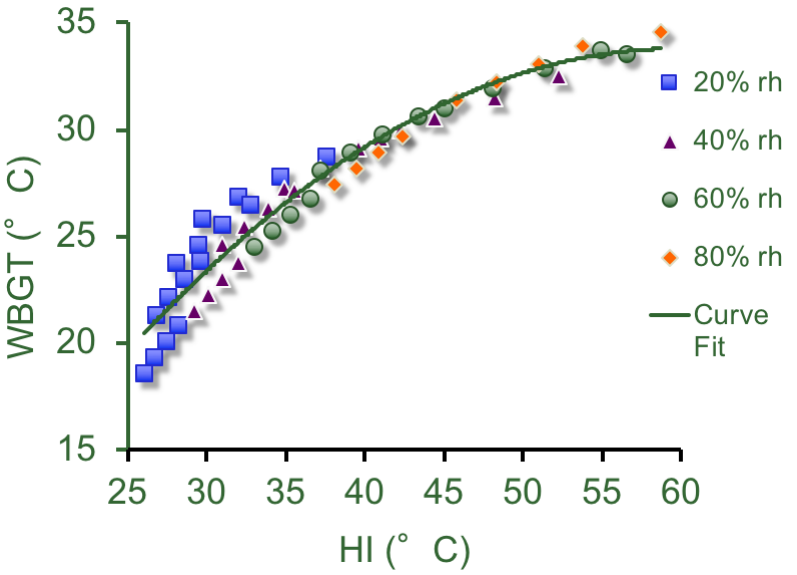
Heat Index

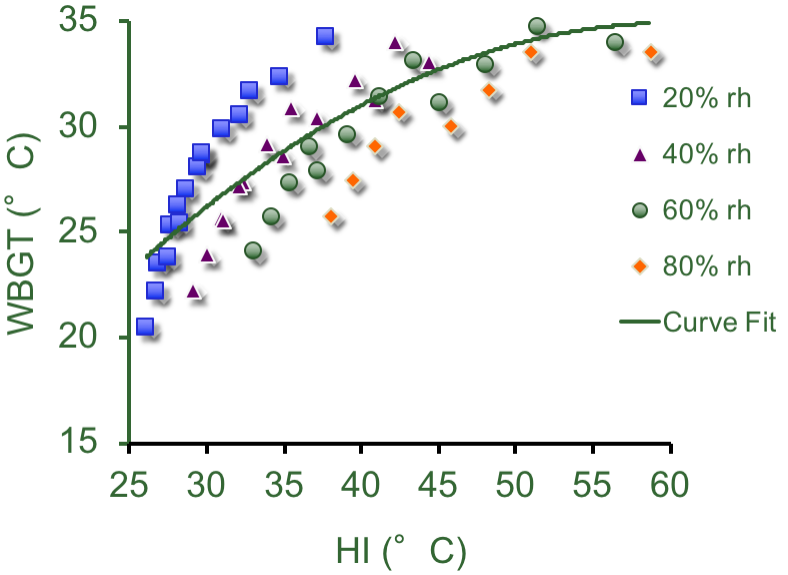
Useful for outdoor work

Heat Index and WBGT

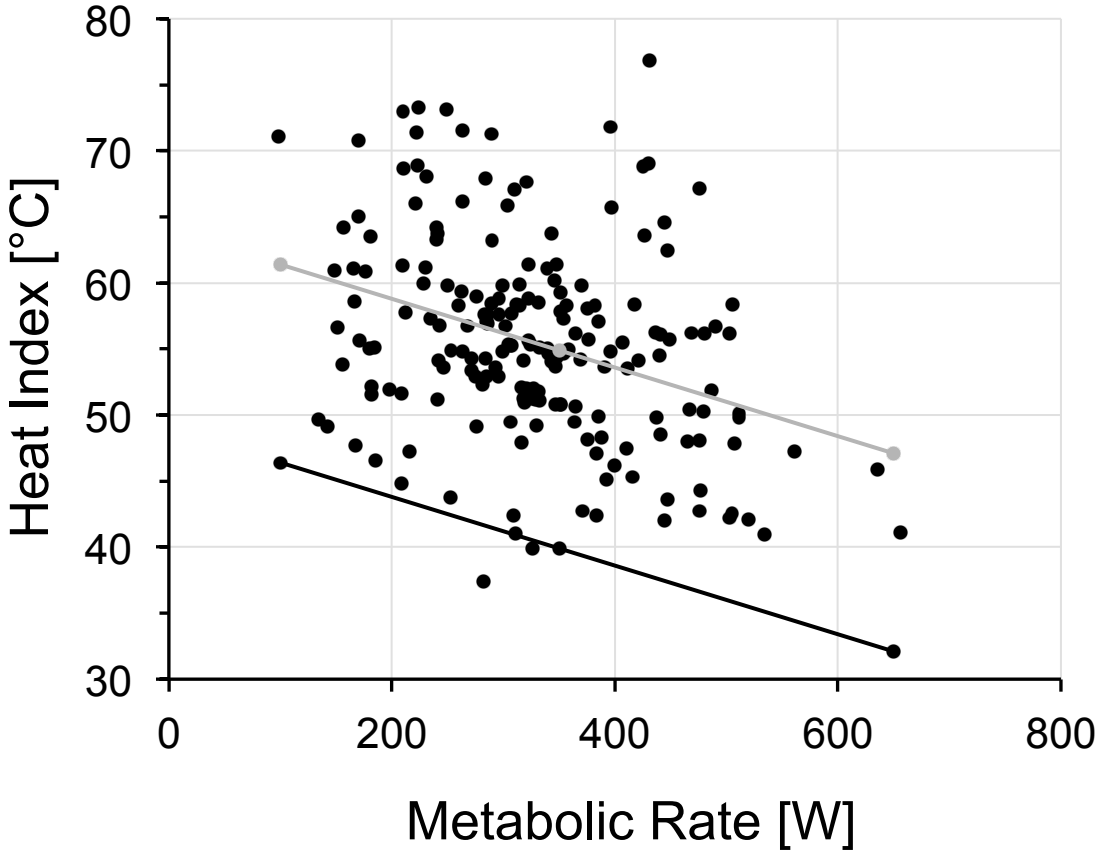
WBGT can be operationalized to Heat Index

- Effect of Sun: $HI_{effective} = HI_{ambient} + 6°F$

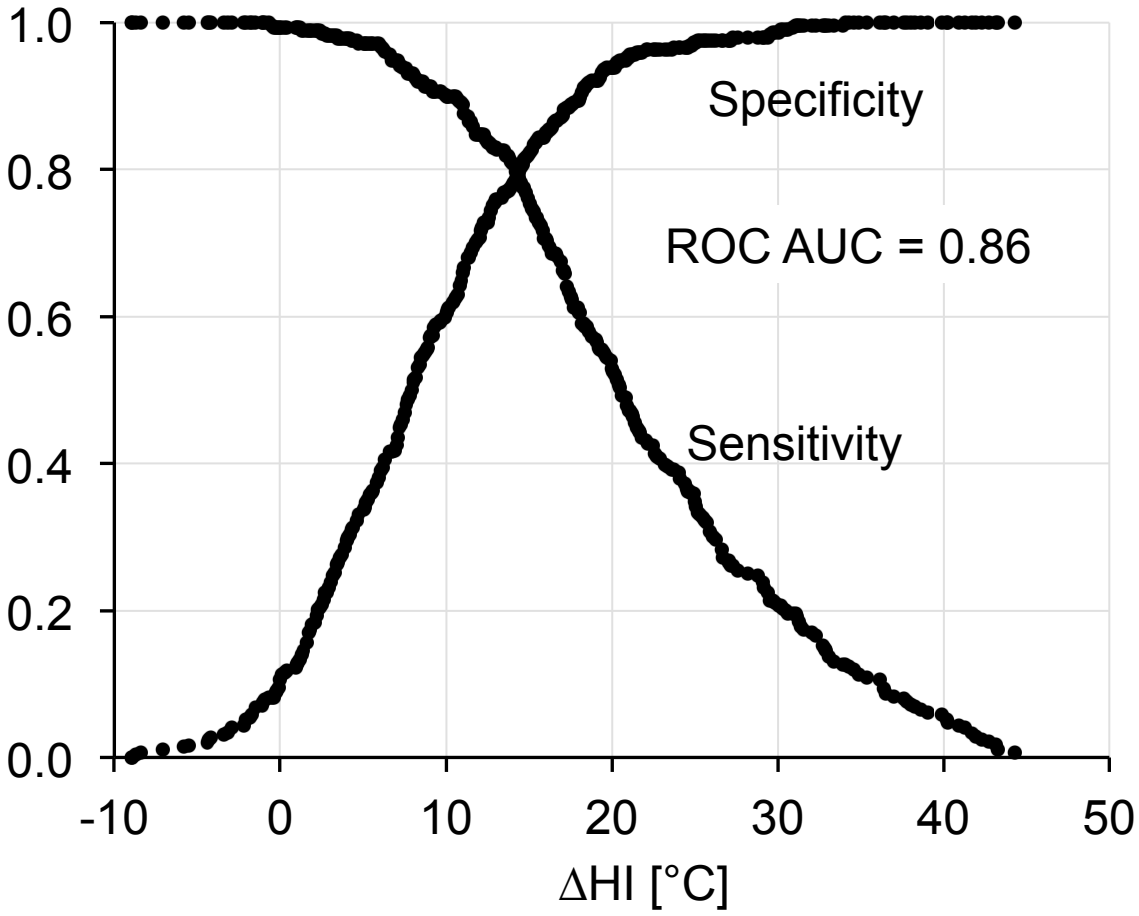




Heat Index as OEL



HI OEL Performance



Clothing Adjustment Values for HI

Clothing Ensemble	CAV [°F-HI]
Work Clothes	0
Particle Barrier Coveralls	3
Water Barrier Coveralls	10
Limited-Use Vapor Barrier Coveralls	33

Wrapping Up

Conclusions

OELs

- High Sensitivity
  - Below OEL: Virtually all individuals exhibited a sustainable exposure
  - As an OEL, it is protective
- Very Low Specificity
  - Above OEL: Many individuals exhibited a sustainable exposure
  - High Rate of False Positives and Credibility Problems

Can account for clothing with CAVs

- Potential problems with high evaporative resistance (e.g., vapor barrier)

Potential for rapid increase in core temperature above individual's critical point

And Some Comments/Advice

There is a risk for exertional heat illness below the occupational exposure limit.

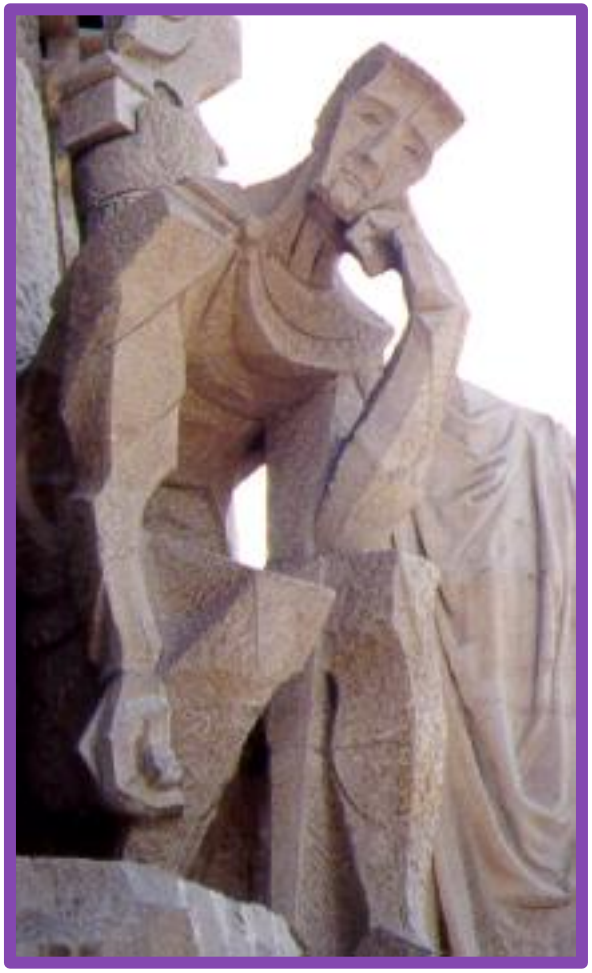
- ACGIH® TLV® for Heat Stress and Strain acknowledges this
- OSHA Office of Occupational Medicine and Nursing has published papers suggesting an alert level for Heat Index > 80°F

Question: Revisit TWAs and Acclimatization Schedule

Identification and counselling for those with personal risk factors

Emergency Response Plan

- Early Recognition of Exertional Heat Stroke
- Appropriate First Aid



Thanks for the opportunity to visit with you

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