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Making a Difference

Heat Stress Management in 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.

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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

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Heat Stress Assessment

--- Background on Standard Stuff ---

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

WBGT-Based Exposure Limits

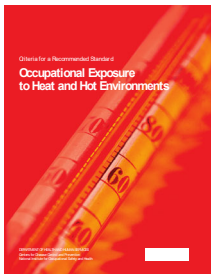
Premise
Performance

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)



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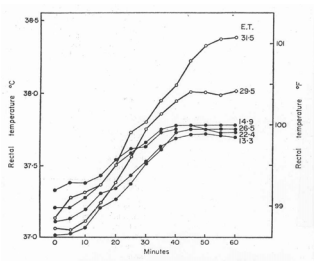
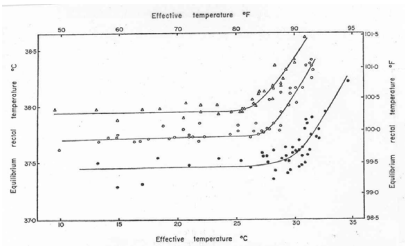
Lind's Observation (1963)

LIND AR. A physiological criterion for setting thermal environmental limits for everyday work. Journal of Applied Physiology 18:51-56, 1963

Upper Limit of the Prescriptive Zone: Transition from Work-Driven to Environment-Driven Core Temperature





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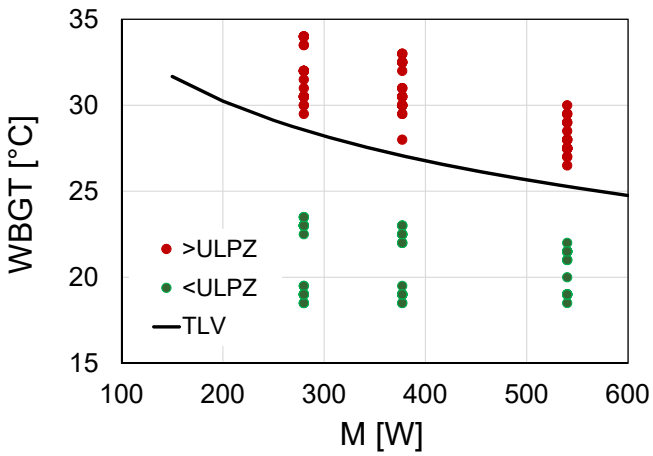
Three Other Studies by Lind

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.



What about Unacclimatized

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

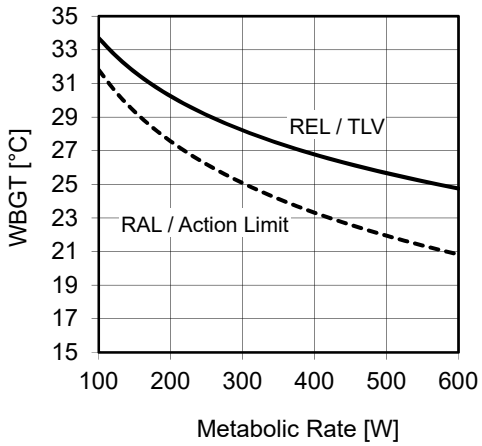
- USF revisit of Kuhlemeier data suggests 3 °C difference

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)



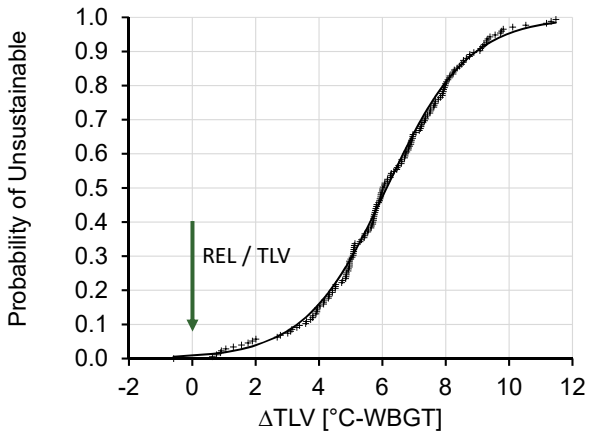
Revisited by USF

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

Exposure-Response Curve



Sensitivity and Specificity Among Studies

Lind

Sensitivity: 0.95 Specificity: 0.69

Kuhlemeier

Sensitivity: 1.00 Specificity: 0.81

USF Progressive Heat Stress Studies

Sensitivity: 1.00 Specificity: 0.07

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)

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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

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PHS Implementations

ISO 7933

- Major change from 2004 edition and some small changes from 2017 draft
- For implementation of 2017 draft see: Ioannou LG, Tsoutsoubi L, Mantzios K, Flouris AD. A free software to predict heat strain according to the ISO 7933:2018. Ind Health. 2019 Nov 29;57(6):711-720. doi: 10.2486/indhealth.2018-0216. Epub 2019 Mar 27. PMID: 30918161; PMCID: PMC6885605 and download for Windows® OS at http://www.famelab.gr/research/downloads/

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

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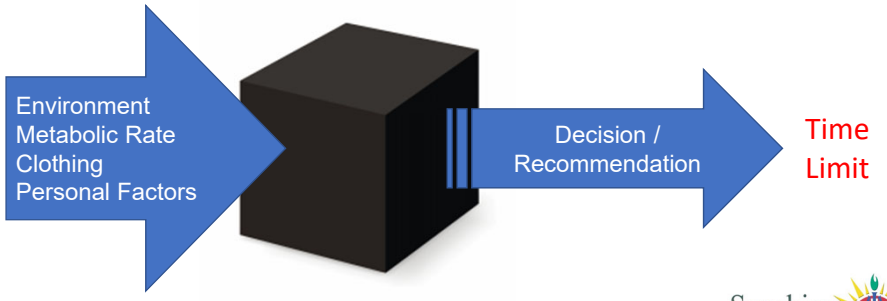
What do we ask of the PHS Black Box?

Is an exposure safe? Yes / No

How long can an exposure safely last?



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Summary of Results for Sustainable Exposures

Clothing	Sensitivity	Specificity
Woven Clothing	1.00	0.18
Particle Barrier	0.95	0.60
Water Barrier	0.91	0.83
Vapor Barrier	0.91	0.80
All Clothing	0.94	0.65

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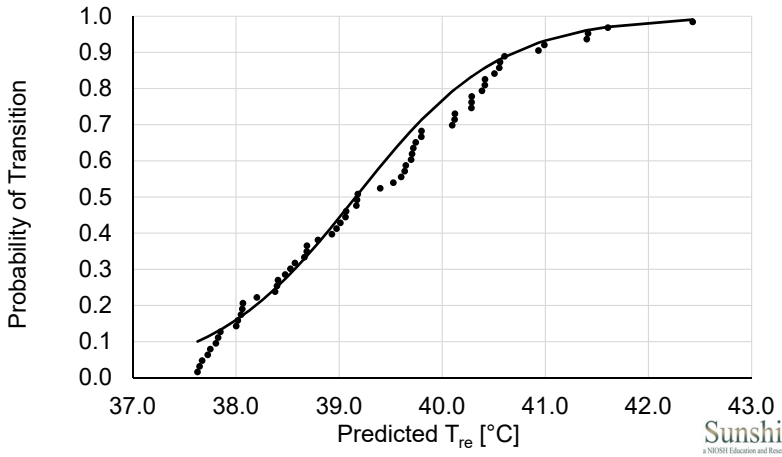
Unsustainable Exposures: Predicted T_{re} at USF Time Limit for Woven Clothing by Fixed Individual Factors



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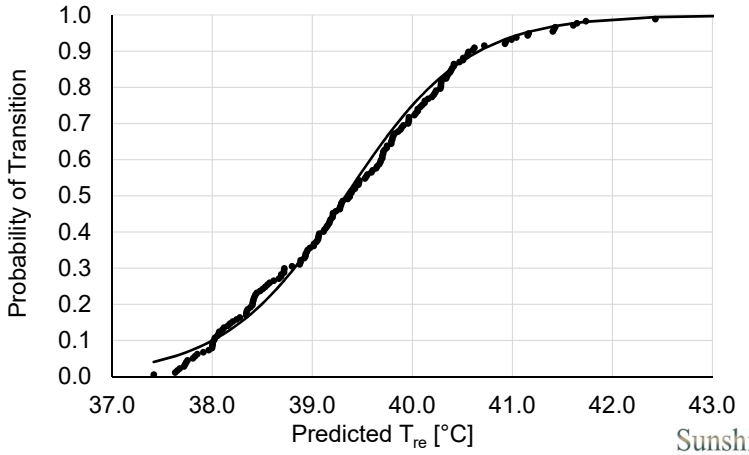
Predicted T_{re} at USF Time Limit
All Clothing by Fixed Individual Factors



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Risk Assessment

--- Novel Suggestions ---

Sustainable Heat Stress Exposures
Excessive Heat Stress Exposures
Time-Limited Exposures

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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

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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

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Summarized in a Table

Heat Stress Level	WBGT [°C]	Risk Description
Acceptable	< 25	• < 1% probability unsustainable exposure for unacclimatized
Caution	25 to 28	• Up to 1% probability unsustainable exposure for acclimatized • Up to about 10% unsustainable exposure for unacclimatized • Up to about 1% excessive exposure for unacclimatized
Moderate	28 to 31	• Up to 10% probability unsustainable exposure for acclimatized • Up to 1% probability excessive exposure for acclimatized • Up to about 50% probability unsustainable exposure for unacclimatized • Up to about 10% probability excessive exposure for unacclimatized
High	31 to 34	• Up to 50% probability unsustainable exposure for acclimatized • Up to 10% probability excessive exposure for acclimatized • Up to about 90% probability unsustainable exposure for unacclimatized • Up to about 50% probability excessive exposure for unacclimatized
Extremely High	> 34	• > 50% probability unsustainable exposure for acclimatized • > 10% probability excessive exposure for acclimatized • > 90% probability unsustainable exposure for unacclimatized • > 50% probability excessive exposure for unacclimatized

Moderate work, ordinary clothing

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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 $WBGT^2$ – 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

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Summarized in a Table

Heat Stress Level	WBGT [°C]	Heat Index [°F]	Heat Index Limits from NIOSH
Acceptable	< 25	< 84	< 80 / 85*
Caution	25 to 28	84 to 94	< 91
Moderate	28 to 31	94 to 106	91 to 103
High	31 to 34	106 to 130	103 to 115
Extremely High	> 34	> 130	< 115

Moderate work, ordinary clothing, direct sun

* OSHA Studies

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And a Heat Index Chart

Moderate work in the sun with regular clothing

	Temperature °F															
RH%	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
20			81	83	85	86	88	90	93	95	97	100	103	106	109	112
25		80	82	83	85	87	89	91	94	97	100	103	106	109	113	117
30		80	82	84	86	88	90	93	96	99	102	106	110	114	118	122
35		81	83	85	87	89	92	95	98	102	106	110	114	119	123	129
40		81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	92	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131			
55	81	84	86	89	93	97	101	106	112	117	124	130				
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	106	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	92	98	105	113	122	131									

Acceptable
Caution
Moderate
High
Extremely High

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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 ---

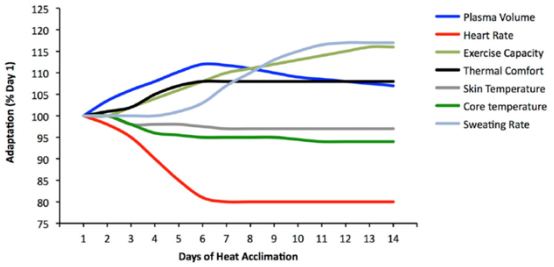
Improvement in Heat Stress Tolerance

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

Day	New	Experienced
1	20%	50%
2	40%	60%
3	60%	80%
4	80%	100%
5	100%	100%

New is appropriate to high skill jobs.

Re-Acclimatization Schedule

Routine Absence	Illness	Exposure Sequence			
		Day 1	Day 2	Day 3	Day 4
< 4	—	100%			
4 – 5	1 – 3	R/E†	100%		
6 – 12	4 – 5	80%	100%		
12 – 20	6 – 8	60%	80%	100%	
> 20	> 8	50%	60%	80%	100%

† Reduce expectations, some loss of capacity

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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 ---

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.

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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

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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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