Hot Worksites and Health: The Risky Business of Working in the Heat

Presenters

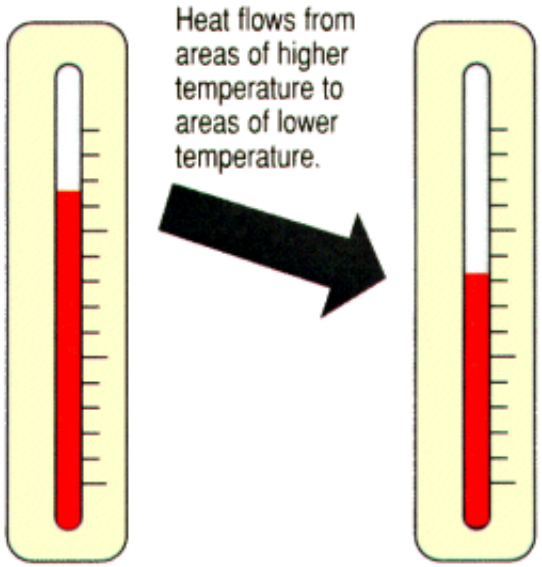
- André Gauvin – Occupational Hygienist
  - Occupational Health Clinics for Ontario Workers (OHCOW)
  - Overview of physiological responses to heat and current heat stress management guidelines
- Keith Birnie – Industrial Hygienist/Ventilation Specialist
  - Workplace Safety North (WSN)
  - Covering heat stress controls, New research surrounding heat stress
- Dr. Sandra Dorman – Full Professor and Director
  - Centre for Research in Occupational Safety and Health (CROSH)
  - Challenges of managing heat stress in extreme conditions

OUTLINE

1. Principles of Heat
2. How your body responds to changes in Temperature
3. Working in the Heat
4. Complications from Heat Stress
5. Heat stress evaluation
6. Humidex heat stress response plan

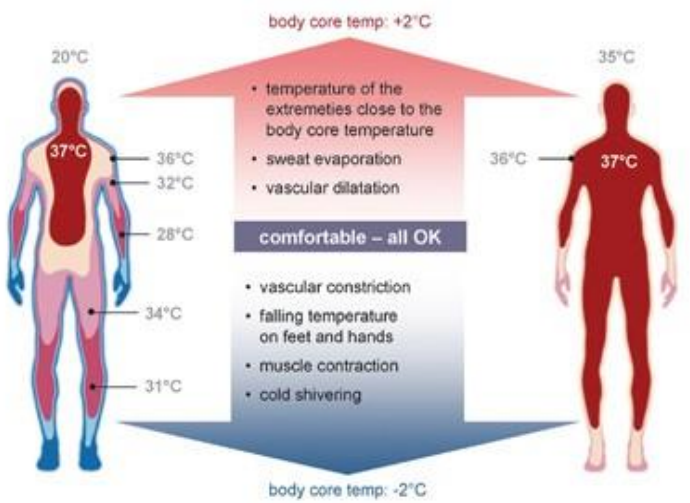
Principles of Heat

- Temperature represents the *energy* of a substance or object.
- *Energy* has the ability to flow from place to another.
- The body keeps its core temperature at ~ 37.5°C ± 0.5°C.



Thermal Balance

- Divisions of the Body
  - Shell (Periphery) Temperature
  - Core Temperature



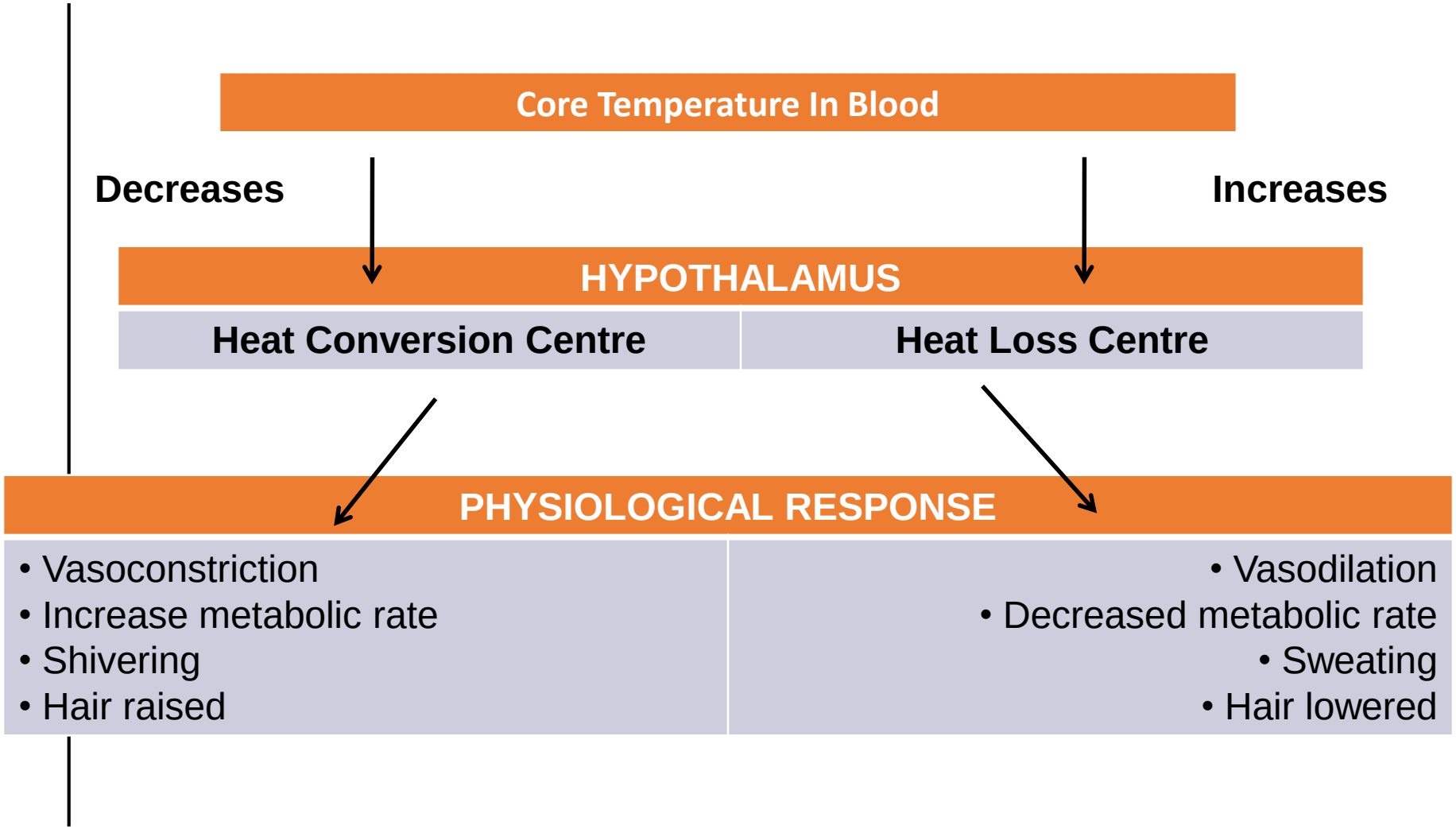
Casa DJ1, McDermott BP, Lee EC, Yeargin SW, Armstrong LE, Maresh CM. Cold water immersion: the gold standard for exertional heatstroke treatment. Exerc Sport Sci Rev. 2007 Jul;35(3):141-9.

Heat Gain versus Heat Loss	Core Temperature
Heat Gain = Heat Loss	Stays the **same**
Heat Gain > Heat Loss	Core temperature **rises**
Heat Gain < Heat Loss	Core temperature **falls**

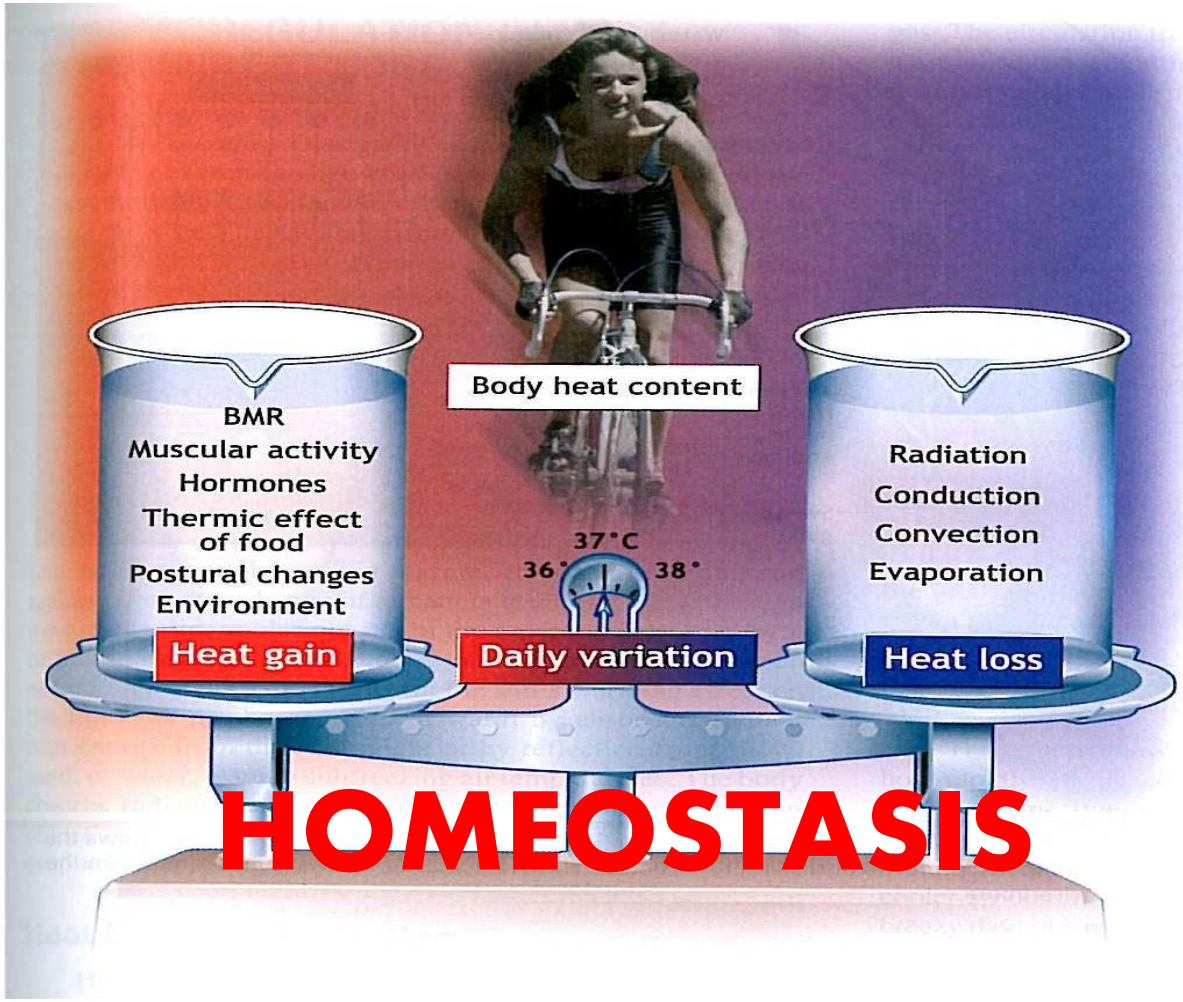
Regulating Temperature

- Thermoregulation
  - Despite variations in temperatures, humans can maintain a constant body temperature by balancing heat gain with heat loss.
- Humans can tolerate a decline in core temperature of 10°C but ONLY an increase of 5°C.

What happens when you get HOT?

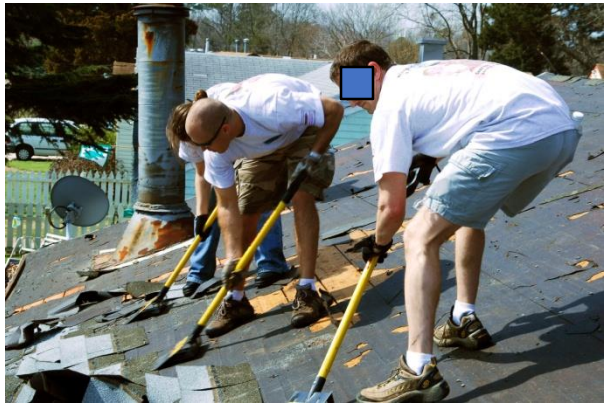


Body Heat Content



Heat Gain

- Resting Metabolism
- *Muscular Activity*
- Thermal Effect of Food
- *Environment*
- Hormones

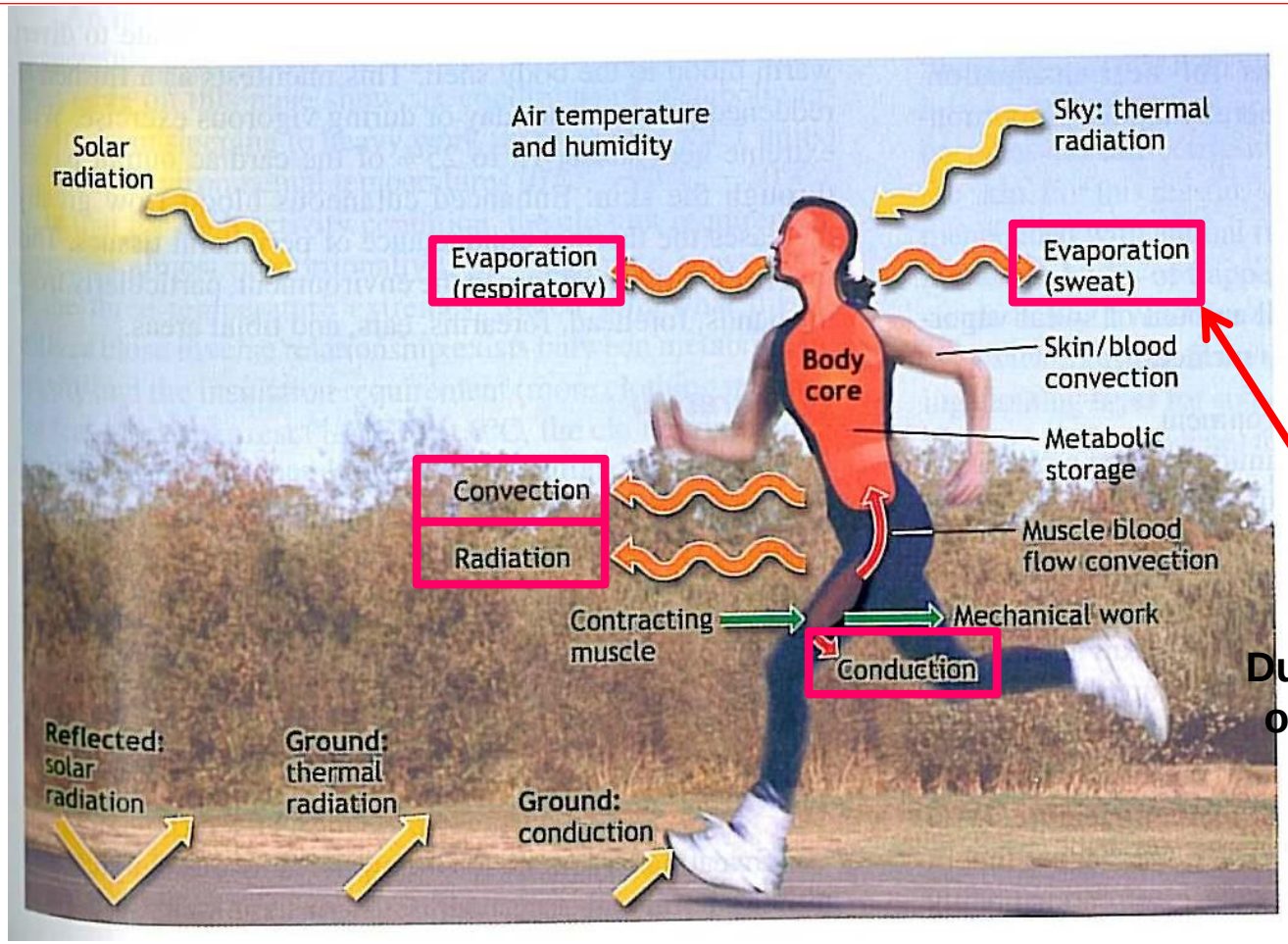


Heat Loss
Thermoregulation In Heat Stress

- The body has thermoregulatory mechanisms that primarily protect against overheating.

- Four Physical Processes Contribute to Heat Loss:
  - Radiation **60%**
  - Conduction **3%**
  - Convection **12%**
  - Evaporation **25%**

Other Heat Loss Processes



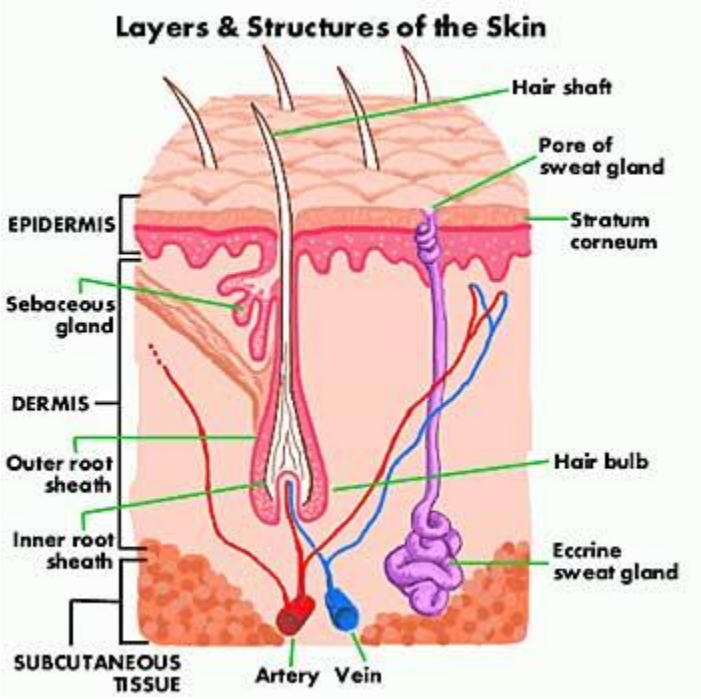
Essentials of Exercise Physiology 3rd (third) Edition by McArdle BS M.Ed PhD, William D., Katch, Frank I., Katch, V (2005)

80%

During Exercise or heavy work load

Heat Loss By Evaporation

- *Evaporation* provides the major defence against over-heating.
  - ❖ The body's surface contains approximately 2 to 4 million sweat glands.
  - ❖ During heat stress, glands secrete sweat.
  - ❖ Evaporation of sweat from the skin exerts a cooling effect (takes it heat from the body).
  - ❖ The cooled skin, in turn, cools the blood diverted from interior tissues.



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Evaporation at High Ambient Temperatures

- As temperature increases, conduction, convection, and radiation decrease in their effectiveness to cool the body.
- In fact, when Ambient Temp > Body Temp:
  - Three processes mentioned above cause the body to gain heat!
- Sweating is the only defense!
  - Skin
  - Respiratory Tract

Heat Loss in High Humidity

- Evaporation of Sweat is Key!
- Three factors affect evaporative cooling
    1. Surface Exposure;
    2. Temperature and Relative Humidity of Air;
    3. Convective air currents around the Body.

Relative Humidity ratio of water in ambient air at a particular temperature to the total quantity of moisture that air could contain (%)

Important

- Sweat does not cool the skin; evaporation cools the skin!!!

the greater the humidity, the greater the risk of overheating!

Factors Determining Physiological Strain

- Air temperature and relative humidity;
- Individual differences in body size and fatness;
- State of Training;
- Degree of Acclimatization;
- Environmental influences such as convective air current and radiant heat gain;
- Intensity of Activity;
- Amount, type, and color of clothing.

Heat Strain Self Evaluation

- Heart beat measurement (sustained 180bpm – age)
- Body temperature (38°C)
- Recovery heart rate @ 1 min. more than 120 bpm
- Symptoms of sudden and sever fatigue, nausea, dizziness, or lightheadedness

Worker may be at risk If

✓Profuse sweating sustained over hrs

✓Weight loss in a shift more than 1.5 %

✓Noticing less frequent urination

Working In the HEAT

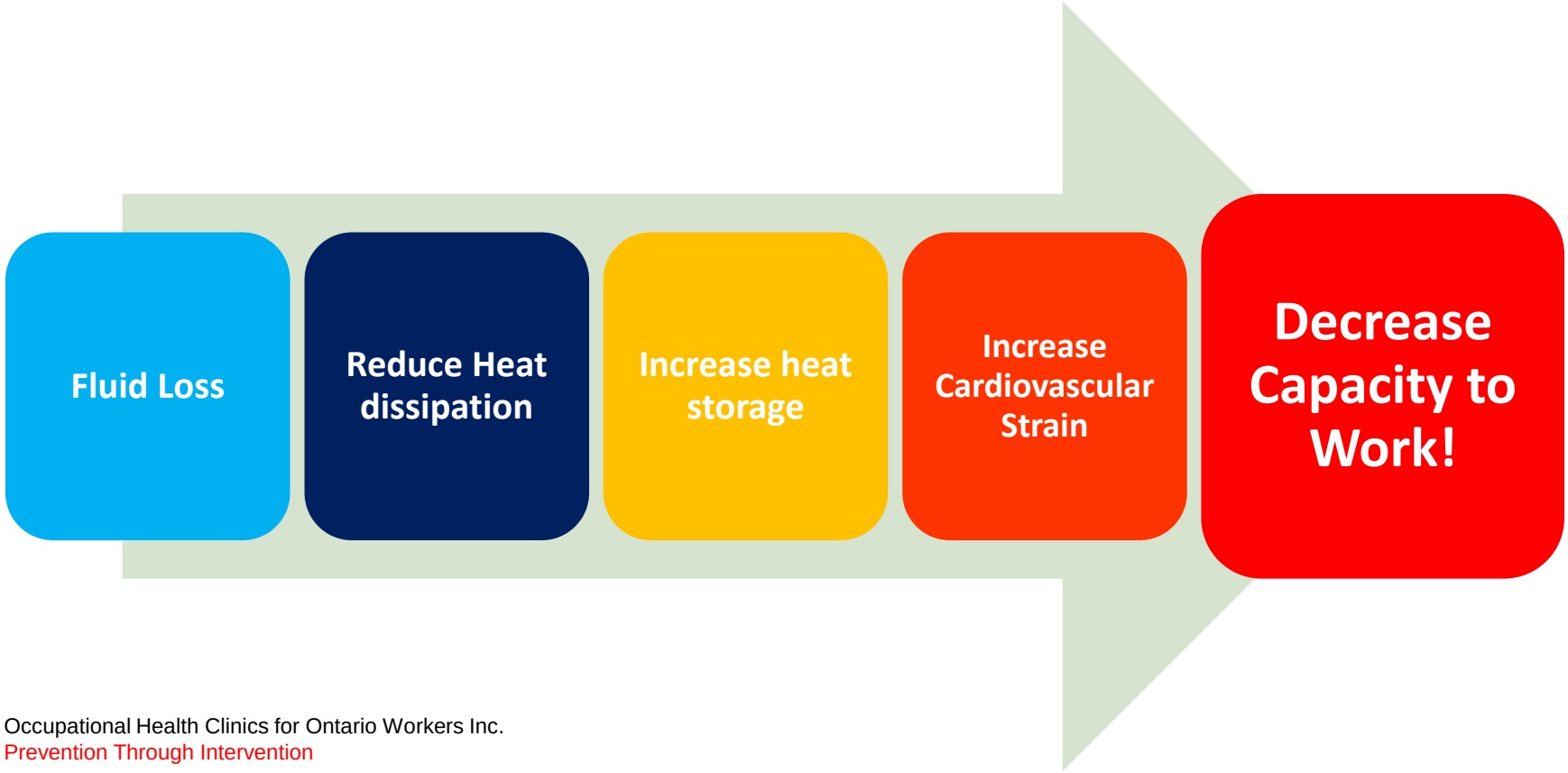
- Physiological Effects
  - Blood Flow
    - Other tissues compromise blood flow
  - Fluid Loss
    - Evaporative cooling
    - Decreased blood volume
  - Core temperature rise
    - Hot environment + Working muscles
    - Core temperature rise causes impaired functioning of brain and fatigue.

Blood Flow in the Heat

- Circulatory Dilemma
  - The body faces two demands when working in the heat:
    1. Muscles require delivery of oxygen through the blood
    2. Blood is diverted to the periphery to transport heat for cooling at the skin surface (oxygen is not delivered)
- <u>DANGER</u>
  - When it comes to exercise/work the body will favour oxygen delivery to the working muscles over cooling mechanisms

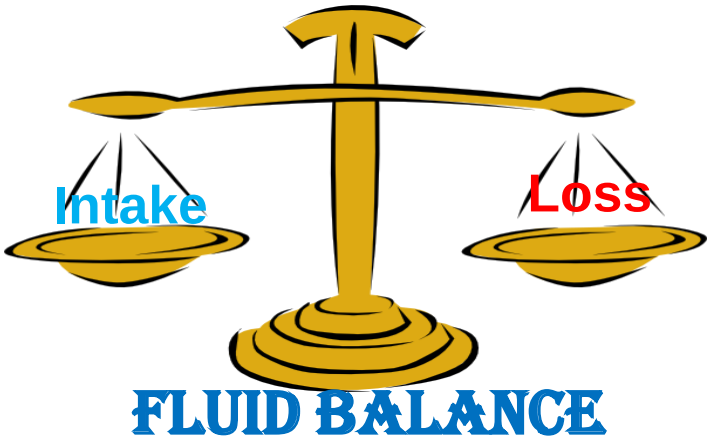
Fluid Loss in the Heat

- Dehydration = body water loss
- 1 hour moderate activity produces a sweat loss of 0.5 to 1 L (or more)



Hydration Strategies

- Hyperhydration – ingesting ‘extra’ water before work in the heat offers thermoregulatory protection.
- Strategy:
    1. 500 mL night before working in heat
    2. Another 500 mL upon awakening
    3. An additional 400 to 600 mL 20 minutes prior to activity.
    4. Consistent fluid intake throughout the day.



Signs of Hydration

- Inadequate Hydration
  - Infrequent urination
  - Excessive weight loss
  - Strong odour of urine
  - Urine Colour
- Adequate Hydration
  - Frequent urination
  - Urine Colour
  - Odourless

Electrolytes

- Electrolytes
  - Electrolyte solutions promote a more complete recovery during rehydration.
    - Decreases urinary output
    - Stimulate thirst mechanism
    - Restores plasma volume more rapidly

Heat Acclimatization

Body will adapt to hot environments over time in several ways including:

1. Improved cutaneous blood flow;
2. Effective distribution of Cardiac Output;
3. Lowered threshold for and increased sweating;
4. More effective distribution of sweat over skin;
5. Lowered salt concentration of sweat;
6. Lowered heart rate for similar activity level.

Heat Acclimatization (2)

- Can take up to 4-7 days to fully acclimatize. ACGIH 2022 TLV suggests: exposed at least 2 hours of heat stress exposure for 5 of last 7 days or 10 of last 14 days

- Noticeable decline after 4 days, and can be completely lost with removal from heat for ~2-3 weeks (i.e. need to re-acclimatize following lengthy vacations).

Those at Higher Risk

- Lack of physical activity
- Poor physical condition
- Overweight
- Age
- Very small body size
- Dehydration
- Excessive clothing
- High alcohol, caffeine, nicotine intake

Occupations at risk

- Involving high air temperatures, radiant heat sources, high humidity, or strenuous physical activities:
  - Construction workers or outdoor workers
  - Iron and steel foundries
  - Underground workers
  - Brick firing and ceramic plants
  - Firefighters
  - Bakeries
  - Smelter workers

Heat Illness

Disabling complications relating to the body's inability to cope with heat:

- Heat Rash
- Heat Cramps
- Heat Exhaustion / Stress / Fainting
- Heat Stroke

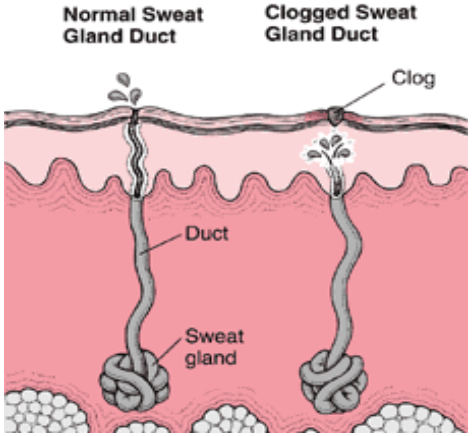
Statistics

- Heat waves claim more lives each year than all other weather-related exposures combined (hurricanes, tornadoes, floods, and earthquakes).
- According to the CDC, between 1979-2003 8,015 deaths were attributed to excessive heat exposure (average of approximately 334 deaths per year).

Heat Rash

Heat Rash

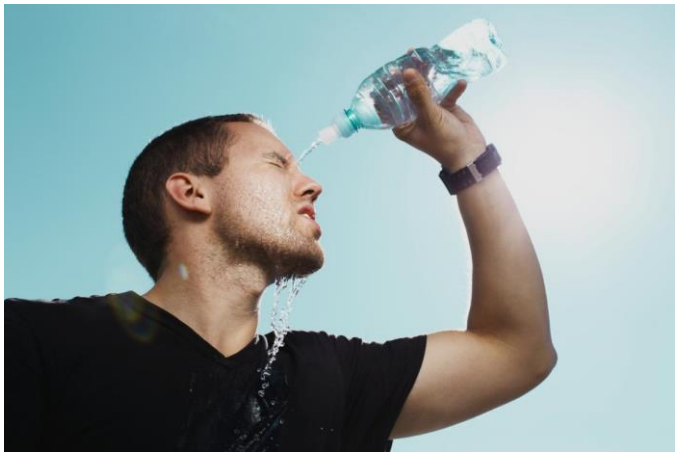
- Heat Rash is an irritation of the skin caused by excessive heat and sweating
- Rash develops as a result of plugged sweat glands (enhanced by hot, humid environment)
- Red, bumpy rash with severe itching.



https://www.merckmanuals.com/home/skin-disorders/sweating-disorders/prickly-heat

Heat Rash - Treatment

- Change into dry clothes and avoid hot environments
- Rinse skin with cool water



Heat Syncope

- Usually occurs in unacclimatized and dehydrated workers during the first heat wave
- Early warning sign of excessive heat strain

- Symptoms include:
  - Fainting (Short duration)
  - Dizziness
  - Light-headedness from standing too long or suddenly rising from a sitting or lying position

- Treatment
  - Sit or lie down in a cool place.
  - Slowly drink water, clear juice, or a sports drink.

Heat Cramps

- Heat Cramps occur during or after physical activity in a hot environment, usually in the specifically exercising muscles.
  - Core temperature often remains normal
  - Heavy perspiration
  - Muscle Cramps (legs, arms, abdomen)
  - Weak/Lightheaded
- Typically caused by an imbalance in the body's fluid level and electrolyte concentrations.
- Heat cramps may also be a symptom of heat exhaustion.

Heat Cramps Prevention

- Rest briefly
- Drink electrolyte-containing drinks (e.g. sports drink) instead of plain water (to prevent water intoxication, or low blood Na level)
- Seek medical help if cramps persist.

Heat Exhaustion

- Heat Exhaustion usually develops in unacclimatized workers during the first heat wave.
- Caused by loss of a large amount of fluids & electrolytes and ineffective circulatory adjustments .
- Warning signs of heat exhaustion:
  - Heavy sweating
  - Paleness
  - Muscle cramps
  - Tiredness / Weakness
  - Dizziness
  - Headache
  - Very Thirsty
  - Nausea or vomiting
  - Fainting

Heat Exhaustion - Treatment

- Move to cool area, loosen clothing; make person lie down; offer sips of cool water.
- It takes at least 30 minutes to cool the body down after overheating
- Get medical attention
- CPR (in cases of cardiac arrest)

Heat Stroke

- Heat stroke is the most serious and complex of the heat stress illnesses.
- Reflects failure of heat-regulating mechanisms from an excessively high core temperature.
- Classic form:
  - Core temp. > 105 F / 40 C
  - Absence of sweating
  - Altered mental status

Heat Stroke

Exertional heat stroke

- Usually occurs in individuals (workers) who engage in:
  - strenuous physical activity for a prolonged period of time in a hot and humid environment.
  - and often have impeded heat dissipation.

Non-exertional heatstroke (NEHS)

- more commonly affects sedentary elderly individuals, persons who are chronically ill, and very young persons.
- NEHS usually occurs during environmental heat waves and is more common in areas that have not experienced a heat wave in many years.

Heat Stroke Progression

- Body no longer able to cool itself
- Basic heat loss mechanisms no longer functioning:
  - High body temperature (may be > 40°C)
  - Starting with excessive sweating → No sweating
  - Hot, dry skin
  - Headache, dizziness, nausea
  - Rapid heart beat, rapid and shallow breathing
  - Confusion, irritability
  - Loss of consciousness
  - Seizures
  - Can lead to death

Heat Stroke - treatment

- Immediate medical attention.
  - Call 911
- Immediate & aggressive cooling (by fanning, removing clothes, spraying with cool water,etc).
- Do not encourage eating
- Give fluid (in small amounts)
- Have the victim lie down with feet elevated, apply cool compresses

ACGIH Heat Stress and Heat Strain TLV®:

- **Threshold limit value (TLV)** applies to “nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers who are repeatedly exposed without adverse health effects.”
- Based on preventing workers' core temperatures from rising above 38°C.
- Developed a method for assessing heat stress based on a wet-bulb globe temperature (WBGT) threshold.

What is a WBGT?

- WBGT (ºC) measures the environmental contribution to heat stress including
  - ➢air temperature (Normal temperature)
  - ➢radiant heat (Globe temperature)
  - ➢Humidity (Natural wet bulb and normal temperature)

2 Ways to calculate

With solar load

WBGT= 0.7NWB + 0.2GT + 0.1DB

Without solar load

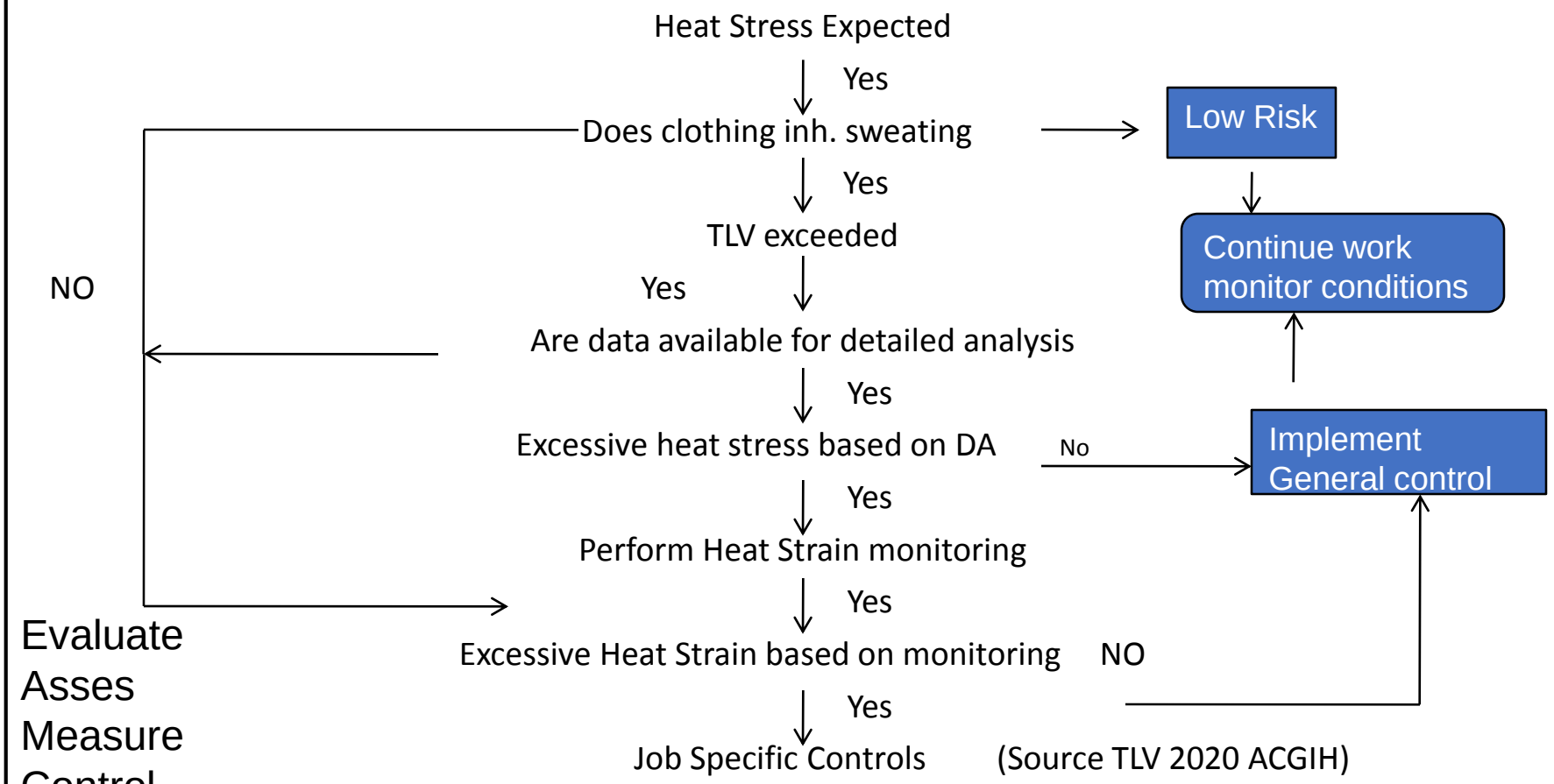
WBGT= 0.7NWB + 0.3GT

ACGIH: TLV and Action Limit for Heat Stress Exposure (WBGT in ºC)

Allocation of work in a cycle of work/recovery	light	moderate	heavy	very heavy
75% to 100% work (breaks incl.)	**31.0** **28.0**	**28.0** **25.0**	**--** **--**	**--** **--**
50% to 75% work	**31.0** **28.5**	**29.0** **26.0**	**27.5** **24.0**	**--** **--**
25% to 50% work	**32.0** **29.5**	**30.0** **27.0**	**29.0** **25.5**	**28.0** **24.5**
0% to 25% work	**32.5** **30.0**	**31.5** **29.0**	**30.5** **28.0**	**30.0** **27.0**

TLV (in ºC) Action Limit (in ºC)

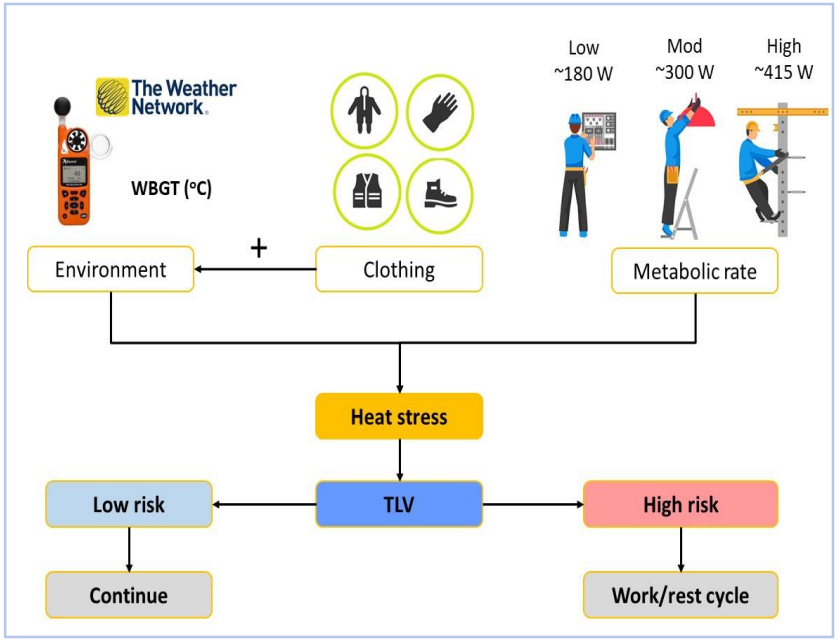
Heat Stress Evaluation

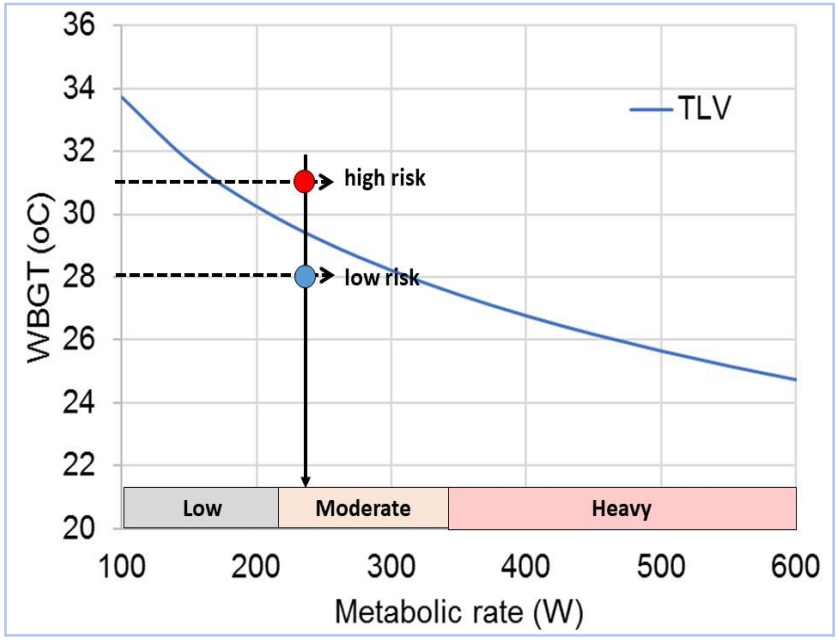


Existing approach for managing heat stress in workers: The ACGIH TLVs

Approach extends upon the simple use of environmental parameters to consider clothing and work intensity.

The prescribed work-rest allocations are based on environmental conditions (WBGT) and estimated work intensity (with adjustments for clothing worn) with the primary goal of maintaining body core temperature within safe limits (≤ 38°C; 100.4°F).





Humidex Heat Stress Response Plan

- Based on the ACGIH TLV.
- WBGT were translated into Humidex.
- Humidex 1: Based on “moderate” workload, un-acclimatized.
  Humidex 2: Based on “moderate” workload, acclimatized.

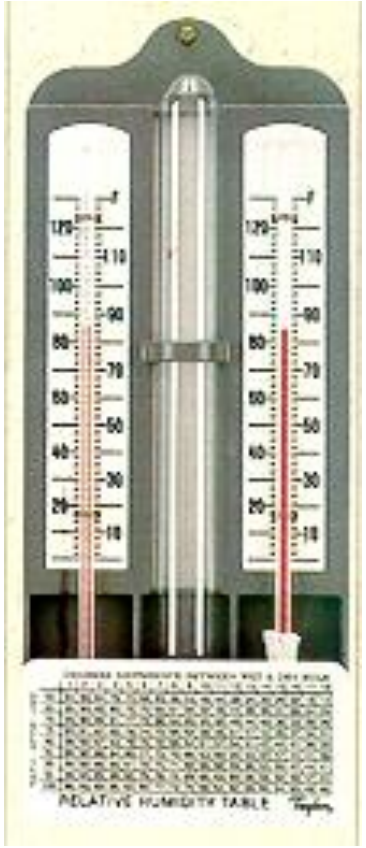
What is Humidex?

Humidex is a Canadian invention to combine temperature and relative humidity into a single number so people can tell how hot it “feels”, for example:

26°C	@ 40% RH	=>	28°C Humidex
	@ 60% RH	=>	32°C Humidex
	@ 80% RH	=>	36°C Humidex
	@ 100% RH	=>	39°C Humidex

How to Measure Humidex:

- Natural wet-bulb and dry bulb thermometers are the most accurate (±2-3%):
  - convert readings to %RH (Relative Humidity)
  - convert %RH and temperature to Humidex
  - (see OHCOW Humidex calculator at www.ohcow.on.ca)
  - Natural wet-bulb temperature: It is measured when the wetted wick covering the sensor is exposed only to naturally occurring air movements.



How to Measure Humidex (2):

- You can also buy hygrometers (RH meters) (about $20-30)
    - Use the table to determine corresponding Humidex.

Occupational Health Clinics for Ontario Workers Inc.

June 2017

Limitations: this table is based on work with **little or no radiant heat**, assuming wearing **regular summer clothing**; if your specific working conditions vary from these assumptions, see the steps 1-5 listed below to make adjustments

Humidex Heat Stress Response Plan

Temp (in °C)	Relative Humidity (in %)																	
	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%	35%	30%	25%	20%	15%	10%
49																			50
48	NEVER IGNORE ANYONE'S SYMPTOMS DESPITE YOUR MEASUREMENTS!!!																		49
47	Moderate Unacclimatized & Heavy Acclimatized							Moderate Acclimatized & Light Unacclimatized										50	47
46																		49	46
45																	50	47	45
44		Action															49	46	43
43	45+	only medically supervised work						50+*								49	47	45	42
42	42-44	work with 45 min/hr relief						47-49*							50	48	46	43	41
41	40-41	work with 30 min/hr relief						45-46*							48	46	44	42	40
40	38-39	work with 15 min/hr relief						43-44						49	47	45	43	41	39
39	34-37	warn for symptoms & extra water						40-42					49	47	45	43	41	39	37
38	30-33	alert for symptoms & extra water						36-39				49	47	45	43	42	40	38	36
37	25-29	water as needed						32-35			49	47	45	44	42	40	38	37	35
36	*for Humidex 45+, heat stress should be managed as per the ACGIH TLV®								50	49	47	45	44	42	40	39	37	35	34
35								50	48	47	45	43	42	40	39	37	36	34	33
34							49	48	46	45	43	42	40	39	37	36	34	33	31
33					50	48	47	46	44	43	41	40	39	37	36	34	33	32	30
32			50	49	48	46	45	44	42	41	40	38	37	36	34	33	32	30	29
31	50	49	48	47	45	44	43	42	40	39	38	37	35	34	33	32	30	29	28
30	48	47	46	44	43	42	41	40	39	37	36	35	34	33	31	30	29	28	27
29	46	45	43	42	41	40	39	38	37	36	35	33	32	31	30	29	28	27	26
28	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
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25	37	36	35	34	33	33	32	31	30	29	28	27	26	26	25				
24	35	34	33	33	32	31	30	29	28	28	27	26	25						
23	33	32	31	31	30	29	28	28	27	26	25								
22	31	30	30	29	28	27	27	26	25	25									
									60%	55%	50%	45%	40%	35%	30%	25%	20%	15%	10%

Ex: Temperature – 29°C

Relative Humidity – 65%

Humidex Heat Stress Plan:

Humidex 1	Response	Humidex 2
25 – 29	supply water to workers on an "as needed" basis	32 – 35
30 – 33	post Heat Stress Alert notice; encourage workers to drink extra water; start recording hourly temperature and relative humidity	36 – 39
34 – 37	post Heat Stress Warning notice; notify workers that they need to drink extra water; ensure workers are trained to recognize symptoms	40 – 42
38 – 39	work with 15 minutes relief per hour can continue; provide adequate cool (10-15°C) water; at least 1 cup (240 mL) of water every 20 minutes worker with symptoms should seek medical attention	43 – 44
40 – 41	work with 30 minutes relief per hour can continue in addition to the provisions listed previously;	45 – 46*
42 – 44	if feasible, work with 45 minutes relief per hour can continue in addition to the provisions listed above.	47 – 49*
45 or over	only medically supervised work can continue	50* or over

Humidex calculator: http://www.ohcow.on.ca/edit/files/general_handouts/heat-stress-calculator.html

*** at Humidex exposures above 45, heat stress should be managed as per the ACGIH TLV®**

Adjustment for Clothing

- Clothing can limit sweat evaporation which causes the body to heat up.
- Results from less air flow between the clothing and skin making sweat evaporation difficult
- TLV (WBGT) is based on wearing long-sleeve cotton shirt and pants.
- When clothing hinders evaporation, value needs to be added to measured temperature, which is based on WBGT.

Clothing adjustment factors

	Current CAV	NIC 2022	Humidex response plan
Clothing Type	**Addition to WBGT ^{0}C**	**Changes to WBGT ^{0}C**	**Changes in humidex ^{0}C**
Short Sleeves and Pants of Woven Material		-1.0	
Work clothes (long sleeve shirt and pants)	0	0	0
Cloth (woven material) coveralls	0	0	0
Double-layer woven clothing	3	3	5
SMS polypropylene coveralls	0.5	0.5	1
Polyolefin coveralls	1	1	2
Limited-use vapor barrier coveralls	11	11	Monitor vital signs
Limited-use vapor barrier coveralls with hood (Full Head and Neck Covering; not face)		+1	
Negative Pressure Respirator (Full Face or Less)		+0	

Protective face masks and Thermoregulation

Protective Face Masks (N95, Air purifying respirators, Surgical masks)

- Negatively impacts respiratory and dermal mechanisms of human thermoregulation (relatively minor increases)
  - impairment of
  - convection,
  - evaporation
  - radiation processes.

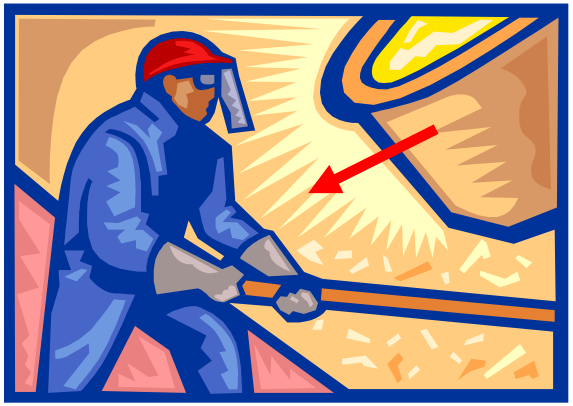
Raymond et al. (2011)., Protective Facemask Impact on Human Thermoregulation: An Overview.

Fletcher et al (Fletcher et al. 2014) looked directly for a Clothing Adjustment Value (CAV) for a full-face negative pressure respirator while wearing a vapor barrier ensemble with hood. They reported a small non-significant difference. For this reason, respirators and other face coverings are assigned a CAV = 0.

Adjustment for Radiant Heat (add to Humidex):

- If working outdoors in direct sunlight between 10 am-4pm, add 2-3ºC to Humidex.

- If working indoors with radiant heat sources, use common sense to add 2-3ºC (compare it to amount received from sun).



Heat Stress Prevention Guidelines

- Summary
  - It important to have a heat stress plan in place when working in the heat
  - Once the risk assessment is complete, controls should be in place to prevent heat related illness.

Thank you for your attention

If you have any questions about ergonomics or any other occupational health concern contact OHCOW at:

Phone: (705)-523-2330/1-800-461-7120

E-mail: sudbury@ohcow.on.ca

Write: OHCOW

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