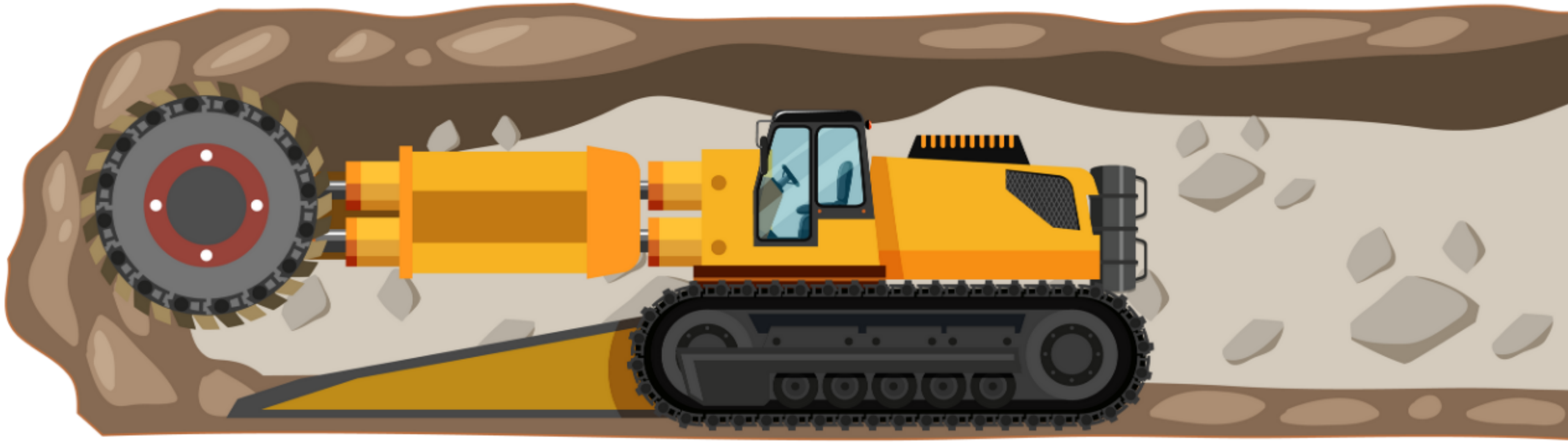
A HOT HISTORY, A HOTTER FUTURE

CREATING A HEAT-RESILIENT WORKFORCE FOR THE MINING INDUSTRY IN THE FACE OF A WARMING PLANET

PART I



Emily Tetzlaff, Ph.D.(c)
School of Human Kinetics
Faculty of Health Sciences
University of Ottawa

HEAT-HEALTH COMMUNICATION IN CANADA
PRESENTATION OVERVIEW

01 PART I Presented by Emily Tetzlaff

- The History of Heat Stress in Mining
- Where Are We Now?
- Where Do We Need to Go From Here?

02 PART II Presented by Dr. Glen Kenny

- A History of Heat Indices
- Underestimation of Heat-Related Illnesses
- Existing Approaches for Managing Heat Stress in Mining
- Translating the Science
- The 'Hang-over" Effect of Heat Stress
- Keeping Your Workers Safe in Extreme Heat

03 KEY TAKE-HOME MESSAGES

- Questions

PART I
THE HISTORY OF HEAT STRESS

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1904 — Report on Cornish Miners and Heat Stress

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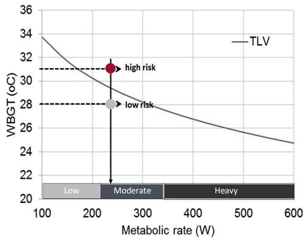
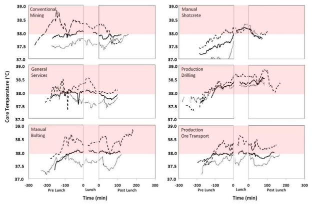


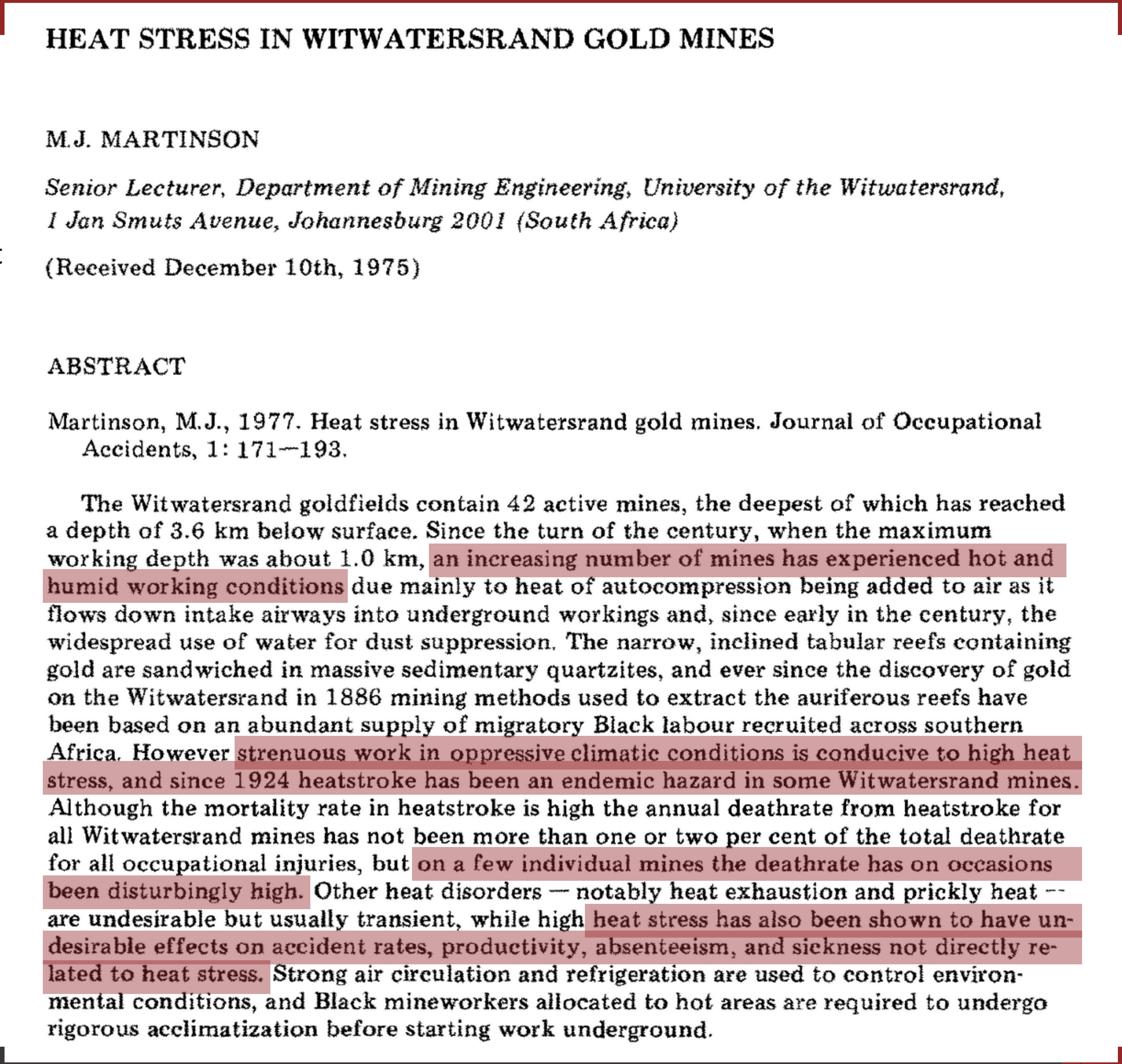
2010s — Workers Continue to Regularly exceed Safe Work Limits



2020s

PART I
THE HISTO

Heat stress in the mining indust


HEAT STRESS IN WITWATERSRAND GOLD MINES

M.J. MARTINSON

Senior Lecturer, Department of Mining Engineering, University of the Witwatersrand, 1 Jan Smuts Avenue, Johannesburg 2001 (South Africa)

(Received December 10th, 1975)

ABSTRACT

Martinson, M.J., 1977. Heat stress in Witwatersrand gold mines. Journal of Occupational Accidents, 1: 171—193.

The Witwatersrand goldfields contain 42 active mines, the deepest of which has reached a depth of 3.6 km below surface. Since the turn of the century, when the maximum working depth was about 1.0 km, an increasing number of mines has experienced hot and humid working conditions due mainly to heat of autocompression being added to air as it flows down intake airways into underground workings and, since early in the century, the widespread use of water for dust suppression. The narrow, inclined tabular reefs containing gold are sandwiched in massive sedimentary quartzites, and ever since the discovery of gold on the Witwatersrand in 1886 mining methods used to extract the auriferous reefs have been based on an abundant supply of migratory Black labour recruited across southern Africa. However strenuous work in oppressive climatic conditions is conducive to high heat stress, and since 1924 heatstroke has been an endemic hazard in some Witwatersrand mines. Although the mortality rate in heatstroke is high the annual deathrate from heatstroke for all Witwatersrand mines has not been more than one or two per cent of the total deathrate for all occupational injuries, but on a few individual mines the deathrate has on occasions been disturbingly high. Other heat disorders — notably heat exhaustion and prickly heat — are undesirable but usually transient, while high heat stress has also been shown to have undesirable effects on accident rates, productivity, absenteeism, and sickness not directly related to heat stress. Strong air circulation and refrigeration are used to control environmental conditions, and Black mineworkers allocated to hot areas are required to undergo rigorous acclimatization before starting work underground.

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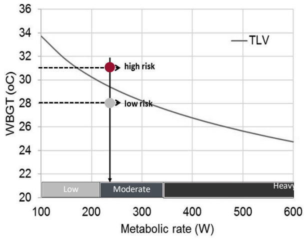

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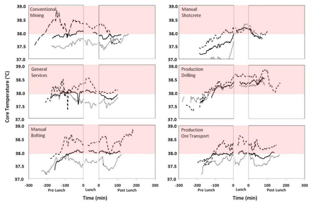

2020s

PART I
THE HISTORY OF HEAT STRESS

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).

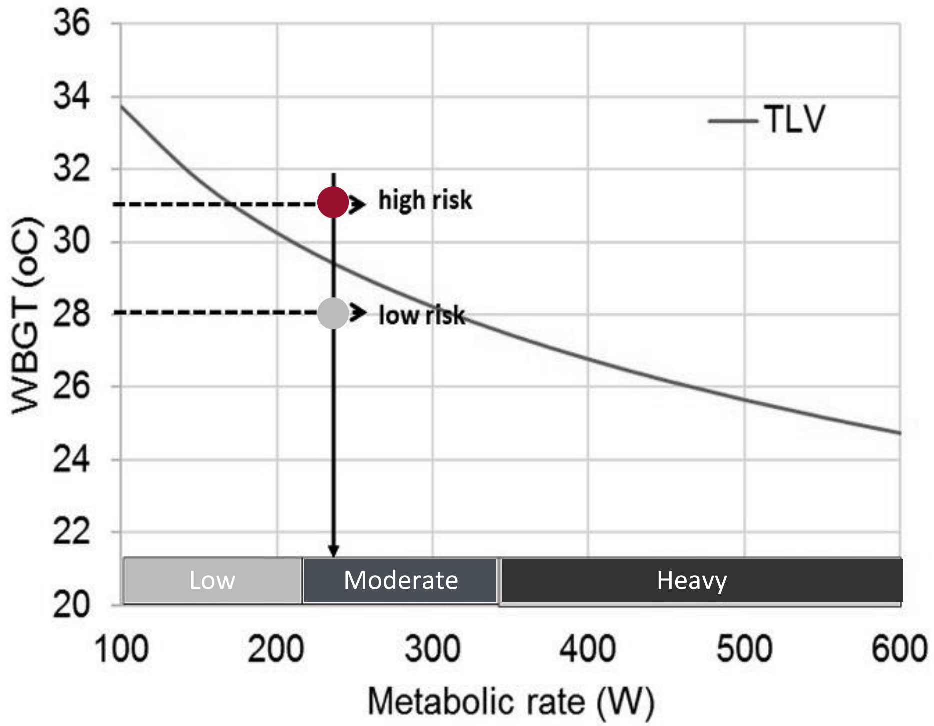

TABLE 2

Numbers of Black mineworkers working at various wet-bulb temperatures: 1956—61

Wet-bulb temperature	Number of men					
	Years 1956—57	1957—58	1958—59	1959—60	1960—61	1956—61
under 26.7°C 80.0°F	82 130	69 759	75 365	73 713	70 335	−14%
26.7—28.8°C 80.0—83.9°F	32 306	32 105	36 870	38 002	38 674	+ 20%
29.8—31.1°C 84.0—87.9°F	28 481	33 937	37 054	38 449	40 610	+ 43%
31.1—32.7°C 88.0—90.9°F	13 509	17 772	19 588	19 477	18 760	+ 39%
32.8—33.8°C 91.0—92.9°F	2 378	3 145	3 635	3 896	4 442	+ 85% (combined with next row)
over 33.9°C 93.0°F	271	405	320	347	455	

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THE HISTORY OF HEAT STRESS

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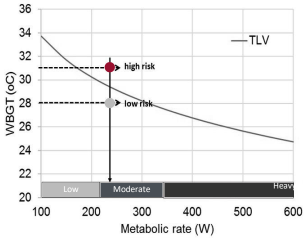

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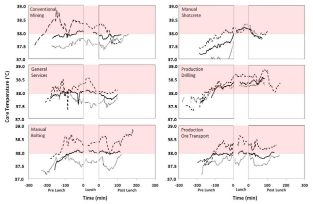


2020s

PART I
THE HISTORY OF HEAT STRESS

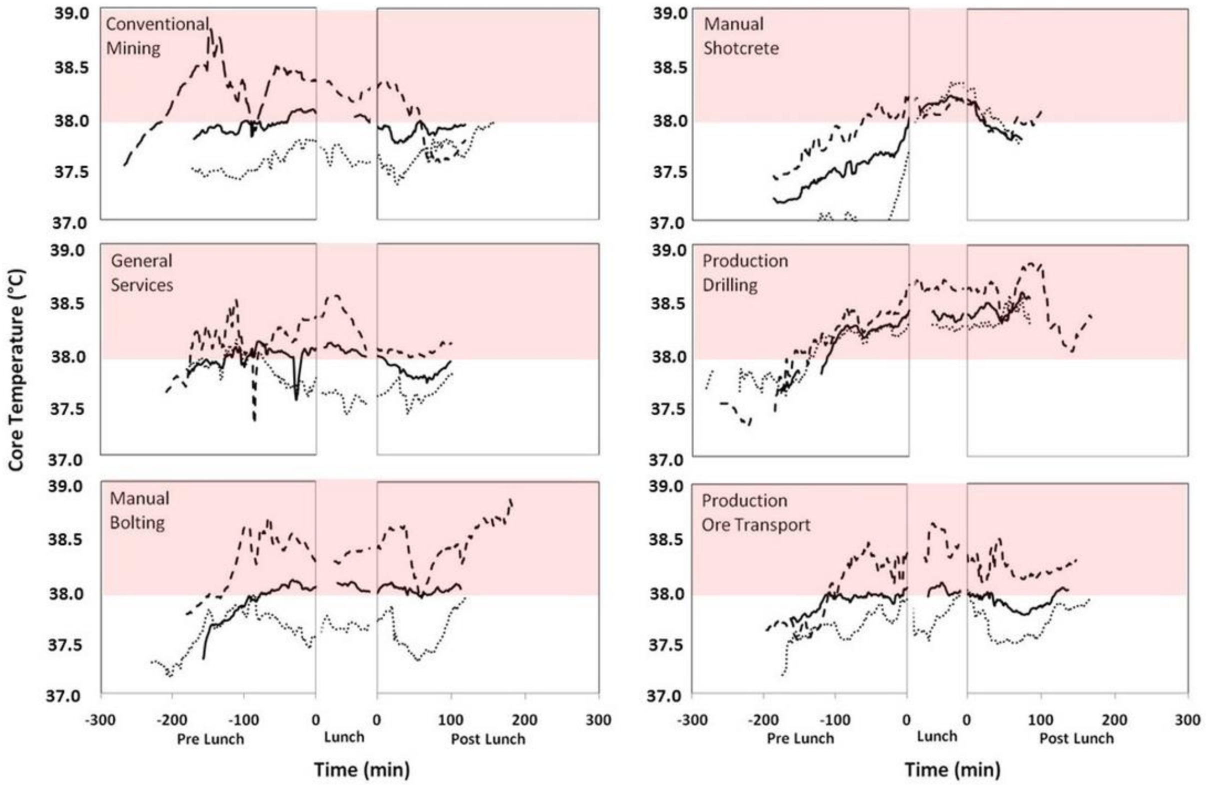
Workers in physically demanding occupations regularly exceed safe work limits, yet it often goes unnoticed.

The work demand, environment and clothing/equipment create a level of heat stress that cannot be adeqautely defended by the body's physiological systems which means workers are at high risk of developing a heat-related illness or traumatic injury.

Miners (USA and Canada) (n=74)

- ~75% of workers achieved sustained core temperatures in excess of 38.0°C.
- ~43% of workers achieved sustained core temperatures greater than 38.5°C.
- ~25% of workers achieved sustained core temperatures greater than 39°C

(J OccupEnviron Hyg. 2012;9:491; Ann Glob Health, 2018,84(3):360)



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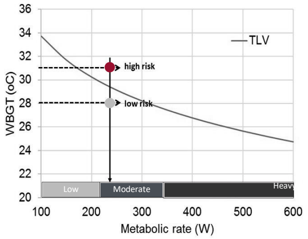

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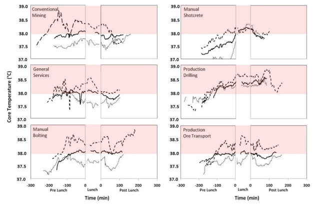

2020s

120 YEARS OF DOCUMENTED EVIDENCE

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PART I
WHERE ARE WE NOW?

We recently launched a Canada-wide survey series to (1) assess current heat risk management methodologies and practices to help determine critical factors and measures of heat stress and heat strain and identify gaps in the safety management system as a whole, and (2) characterize the key determinants of heat stress and strain by sector (i.e. underground, open-pit) to support the development of standardized heat management practices.

88% of employees reported that their job exposes them to heat stress, with 64% completing their duties daily or almost daily, and for >2 hours of their shift (61%).

75% of managers indicated that heat stress is a problem at their work site.

Employees reported various HRIs, including heat rashes (23%) heat exhaustion (21%), significant in-shift weight loss (17%), heat cramps (14%), heat stroke (7%), heat fatigue (7%), and heat edema (6%).

"the initial shock to my system was extreme. I had significant difficulty dealing with the environment...I lost 30lbs, in the initial 30 calendar days after starting work."

78% of managers reported having heat stress management programs, with 69% relying on the American Conference of Governmental Industrial Hygienists guidelines. 55% do pre-task assessments, 31% do post-task reviews and only 6% do pre-employment screening.

Only 47% of sites perform personnel heat strain monitoring or assessments.

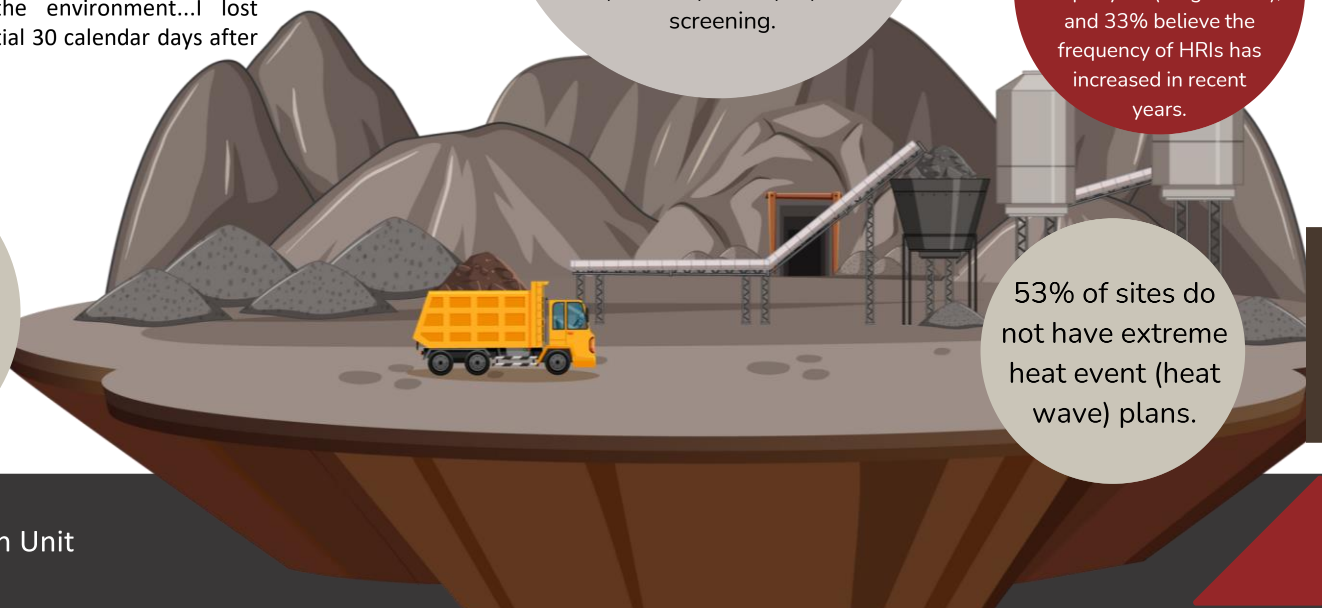
47% of managers reported lost time due to HRIs, with an average of 3.5 per year (range: 0-30), and 33% believe the frequency of HRIs has increased in recent years.

89% of employees indicated they would report signs and symptoms of HRIs to their supervisor.

In contrast, 67% of managers indicated that they feel employees do not report all HRIs.

53% of sites do not have extreme heat event (heat wave) plans.

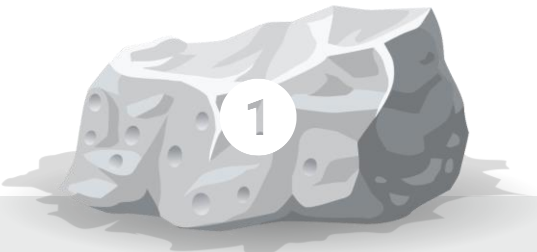
Based on the HSSI, 24% of workers are at HIGH risk for HRIs, and 41% are at MODERATE risk for HRIs.



PART I

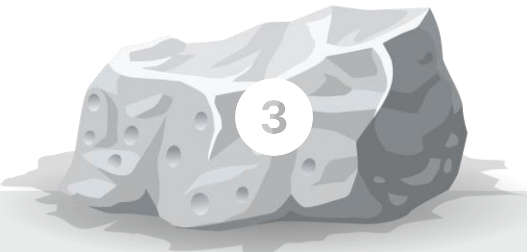
WHERE DO WE NEED TO GO FROM HERE?

Heat stress is a deadly occupational hazard that is projected to increase in severity with global warming. While upper limits for heat stress designed to protect all workers have been recommended by government and occupational safety institutes for some time (e.g., ACGIH guidelines), heat stress continues to compromise health and productivity.



Nearly all workers in the mining industry experience moderate to high levels of heat strain - due to environmental heat exposure or due to metabolic demand and personal protective equipment.

Rise of global warming is placing traditionally temperate regions at risk for extended heat periods and heat waves.



Changing industry demographics - an aging workforce, retention of employees, new hires, and female workers.

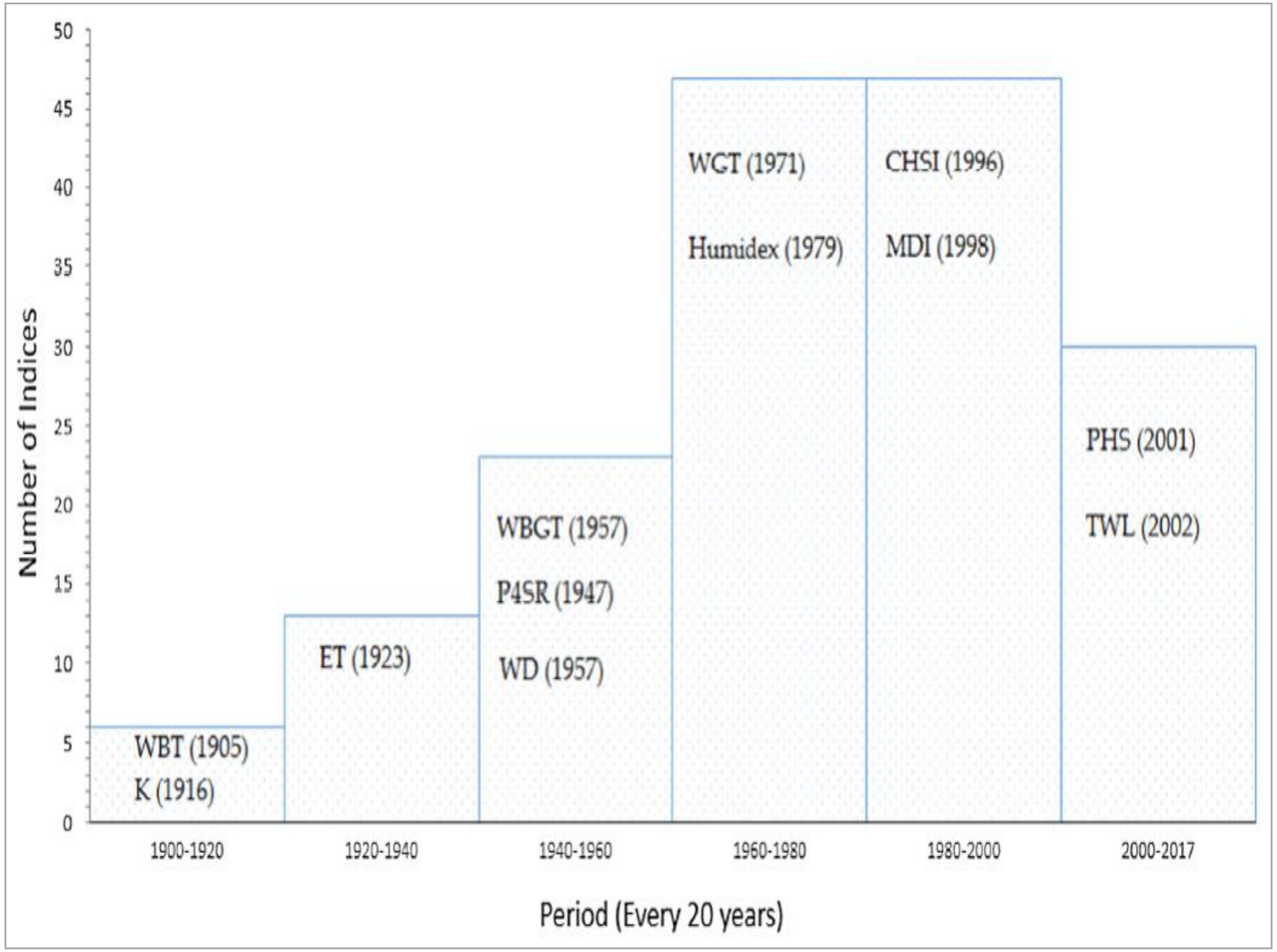
Eliminate one-size-fits all approaches to heat stress management.

A Hot History, a Hotter Future: Creating a Heat-Resilient Workforce for the Mining Industry in the Face of a Warming Planet – Part II

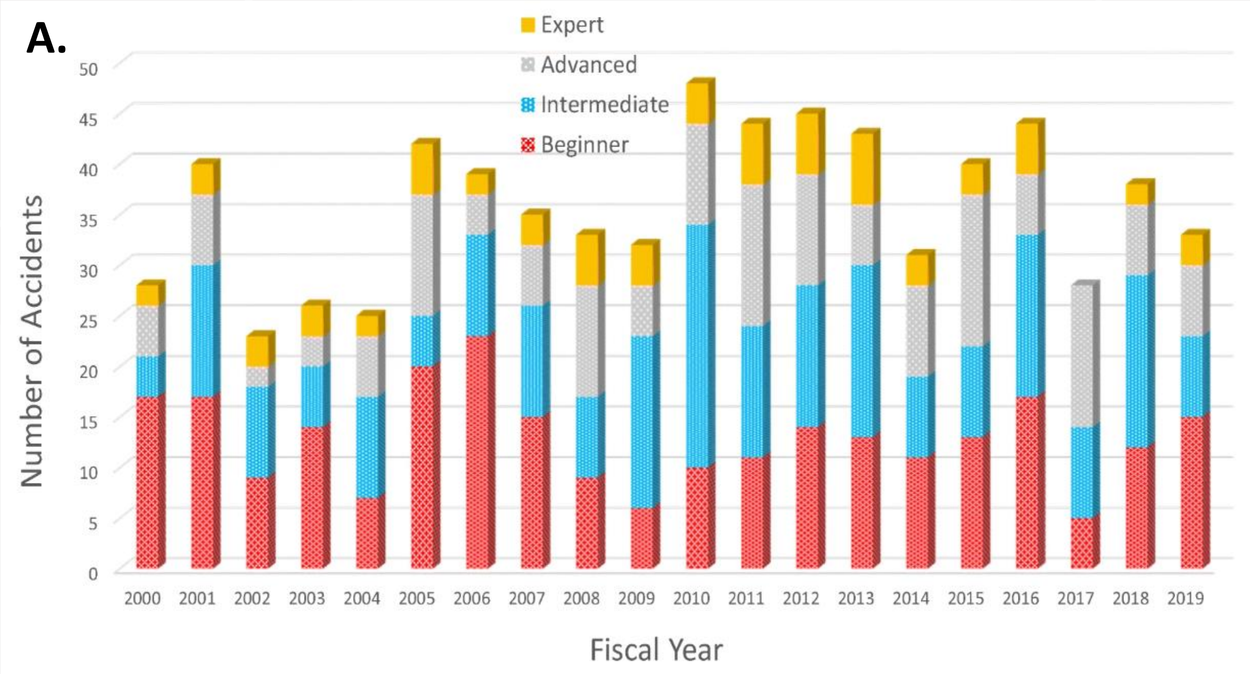
Glen P. Kenny; PhD (Med), FCAHS, FACSM
Professor
Industry Research Chair (Heat Strain Monitoring and Management)
Director, Human and Environmental Physiology Research Unit
University of Ottawa, Ottawa, ON.

A historical view of the 167 heat indices highlighting the most distinguishing characteristics of each period

Mining, Metallurgy & Exploration (2021) 38:497–508



(Note: 187 thermal stress indicators – Temperature, 2022;9:227)



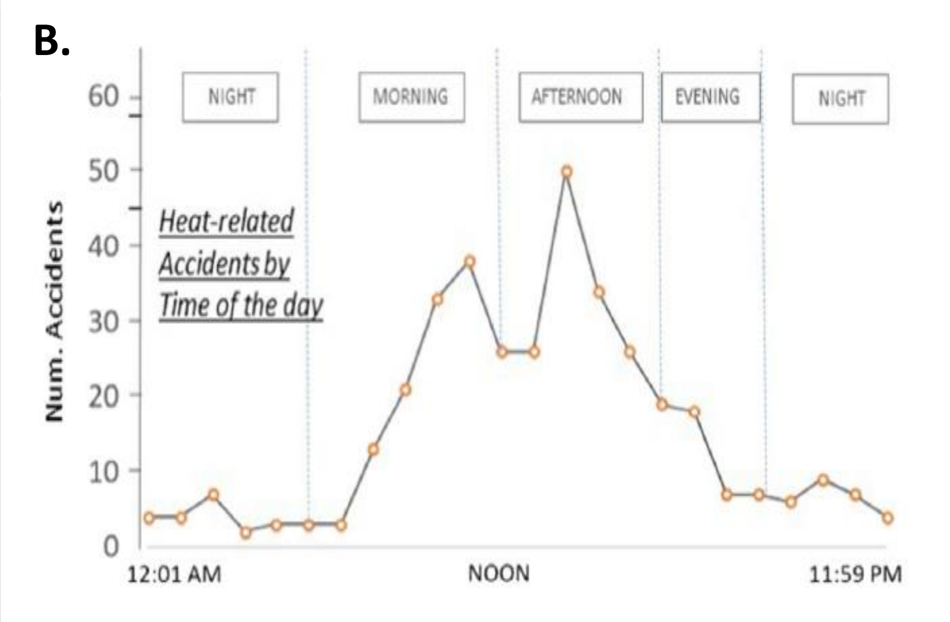
Panel A. Number of heat-related accidents in the mining industry (surface and underground) by level of experience: beginner (0–1 year), intermediate (1–5 years), advanced (5–15 years), and expert (> 15 years). Data: Mine Safety and Health Administration (MSHA).

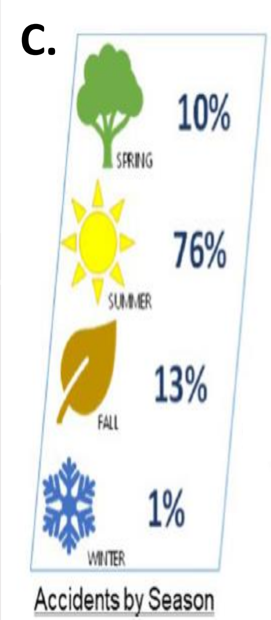
Number of cases under-estimated for several reasons:

- surveillance of heat-related illnesses is inadequate (J Occup Environ Med. 2006, 48:357),
- heat illnesses are often misdiagnosed (Am Fam Physician. 2010;82:169), and
- criteria to define heat-related illness often differs (Am (J Foren Med Path. 1997;18:11).

Workers may not report heat-related illness to employers due to (Am J Ind Med. 2015;58:203):

- fear of discipline or termination,
- economic incentives, and
- Other.





Number of heat-related accidents in the underground mining industry from 2010 until September 2019 (**Panel B**). and by season (**Panel A**). Data obtained from MSHA.

Mining, Metallurgy & Exploration (2021) 38:497–508

2018

Evaluation of Occupational Exposure Limits for Heat Stress in Outdoor Workers — United States, 2011–2016

Aaron W. Tustin, MD,[1] Glenn E. Lamson, MS,[1] Brenda L. Jacklitsch, PhD,[2] Richard J. Thomas, MD,[1] Sheila B. Arbury, MPH,[1] Dawn L. Cannon, MD,[1] Richard G. Gonzales,[3] and Michael J. Hodgson, MD[1]

MMWR Morb Mortal Wkly Rep. 2018 Jul 6; 67(26): 733–737.

A Heat Index screening threshold of 85°F (29.4°C) could identify potentially hazardous levels of workplace environmental heat

In our opinion this recommendation was a dangerous step backwards.

2019

COMMENTARY

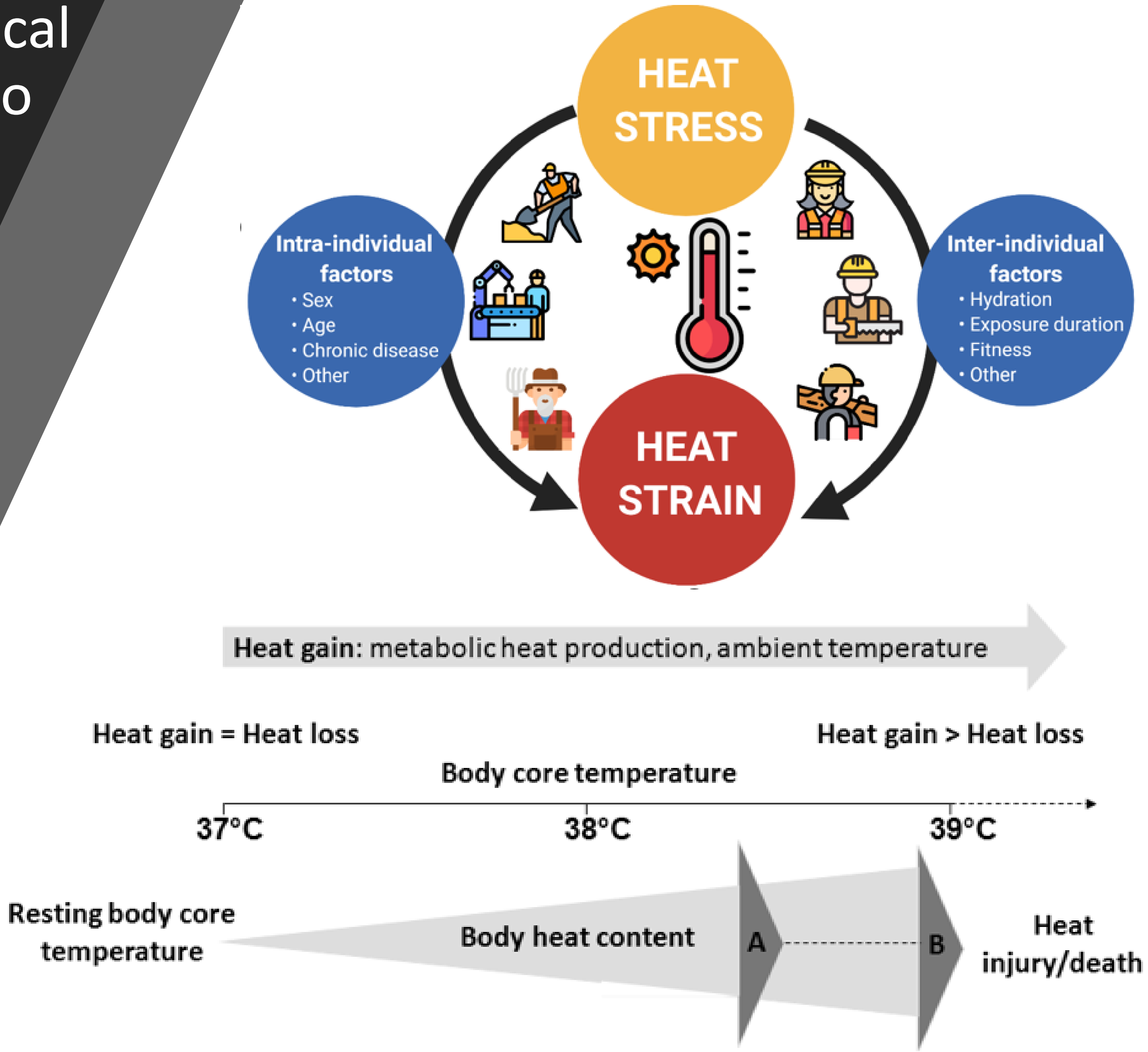
WILEY AMERICAN JOURNAL OF INDUSTRIAL MEDICINE

Occupational heat stress management: Does one size fit all?

Sean R. Notley[1] | Andreas D. Flouris[1,2] | Glen P. Kenny[1] *Am J Ind Med.* 2019;1–7.

An individualized approach to occupational heat stress management is of critical importance to protecting worker health and maximizing productivity

Heat strain is the overall physiological response resulting from exposure to a *heat stress*.



Existing approach for managing heat stress in workers

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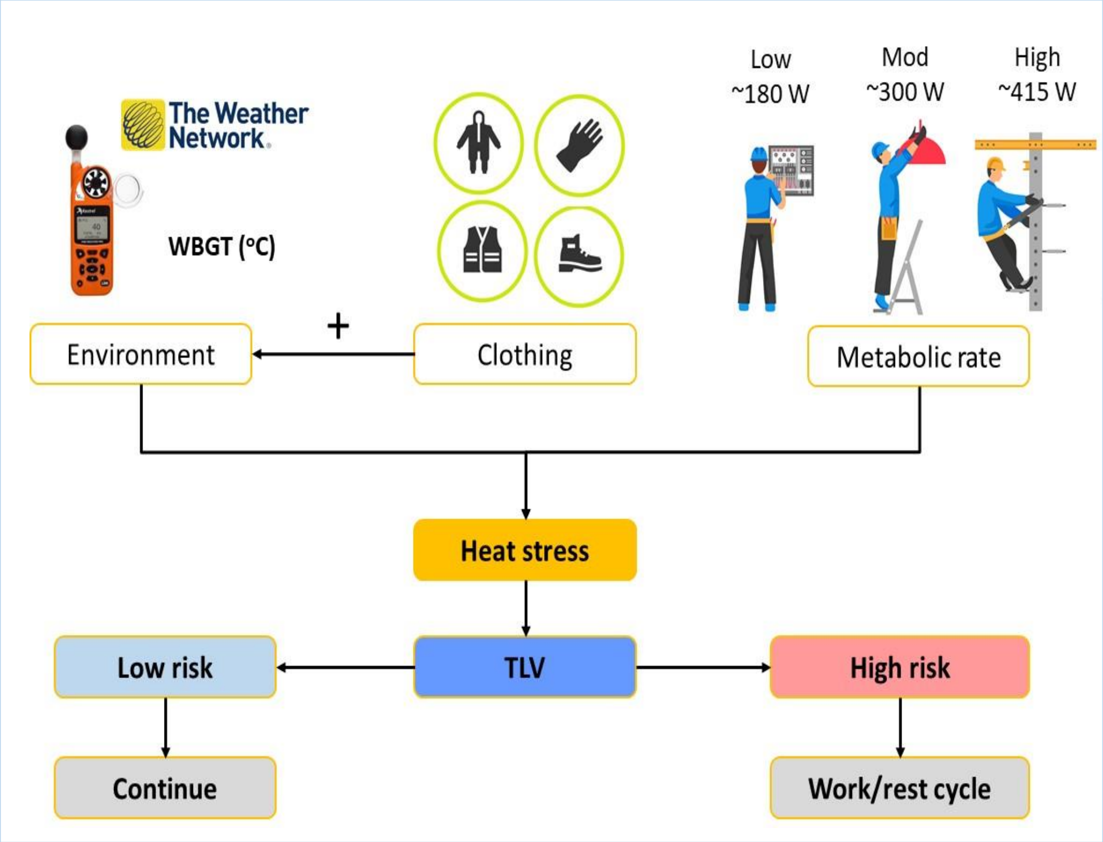
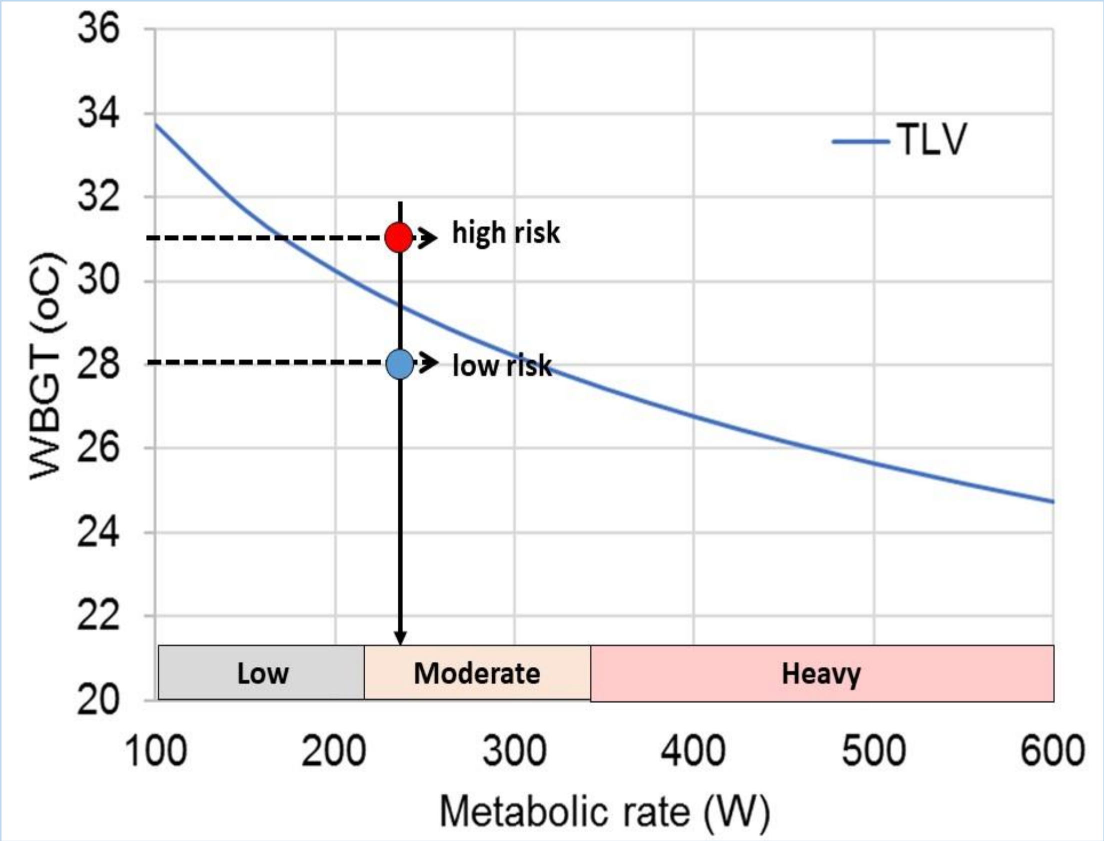
Approach extends upon the simple use of environmental parameters to consider clothing and work intensity.

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).





Heat stress remains a challenge for the mining industry

Workers in physically demanding occupations regularly exceed safe work limits, yet in most cases it goes unnoticed.

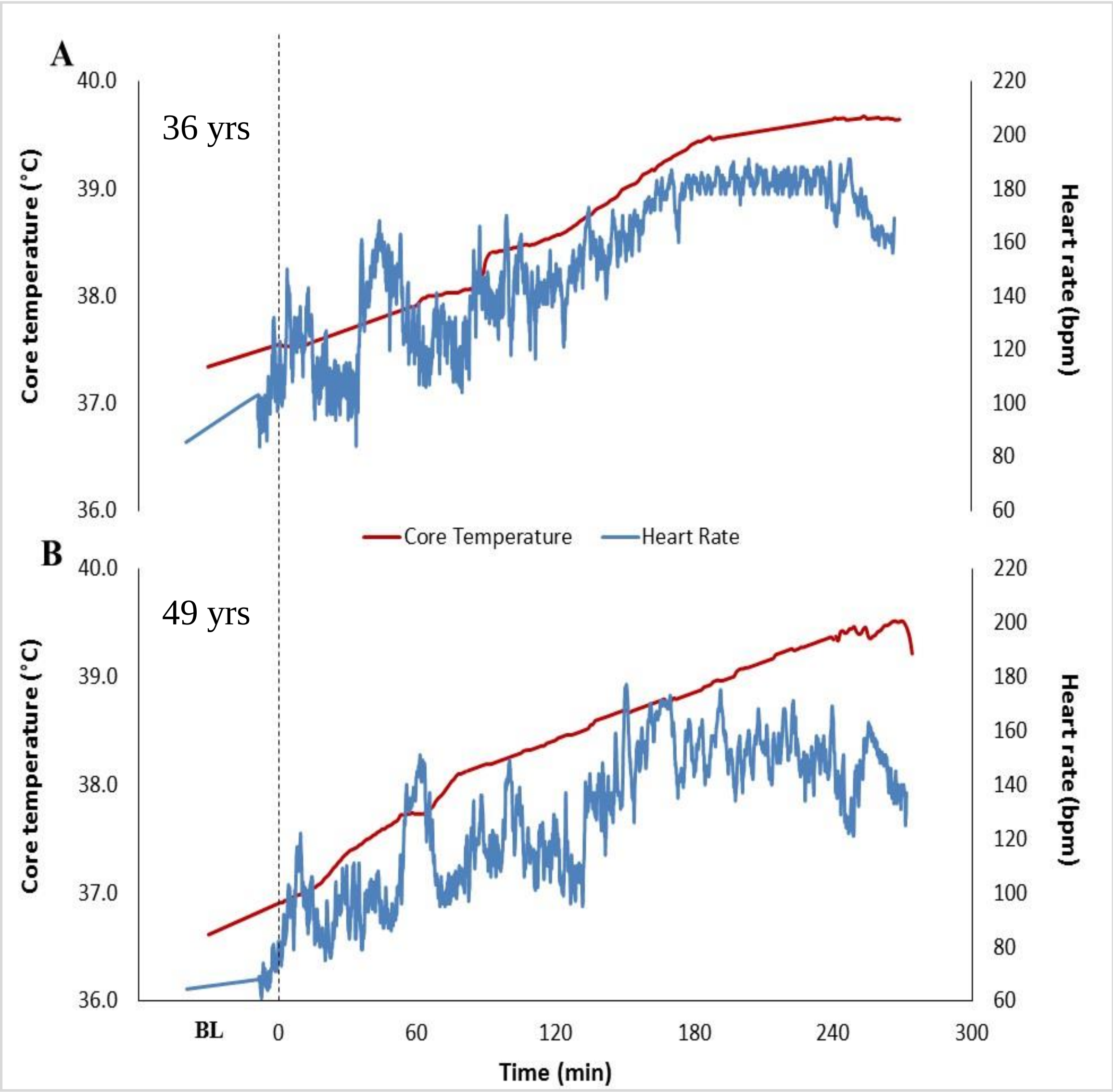
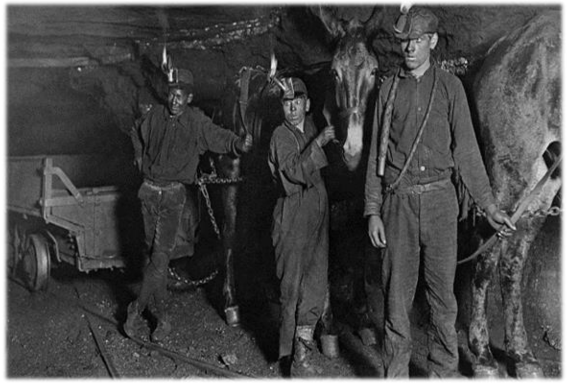


Figure. Example of workers who experienced a severe heat injury.



Miners (USA and Canada)

- **~70%**, sustained core temperatures >38.0°C.
- **~40%**, sustained core temperatures >38.5°C.
- **~25%**, sustained core temperatures >39.0°C.

(J Occup Environ Hyg. 2012;9:491; Ann Glob Health. 2018,84(3):360)

Why is this a problem?

The work demand, environment and clothing/equipment creates a level of heat stress that cannot be adequately defended by the body's physiological systems which means workers are at high risk of developing a heat-related illness or traumatic injury.

Current heat management guidelines are not protective

- Workers suffer excessive heat strain despite following work guidelines.
- Guidelines do not consider the diverse working population and the factors that modulate a worker's heat tolerance from day-to-day.

Allocation of Work in a Cycle of Work and Recovery	TLV® (WBGT values in °C)			
	Light	Moderate	Heavy	Very Heavy
75% to 100%	31.0	28.0	—	—
50% to 75%	31.0	29.0	27.5	—
25% to 50%	32.0	30.0	29.0	28.0
0% to 25%	32.5	31.5	30.5	30.0

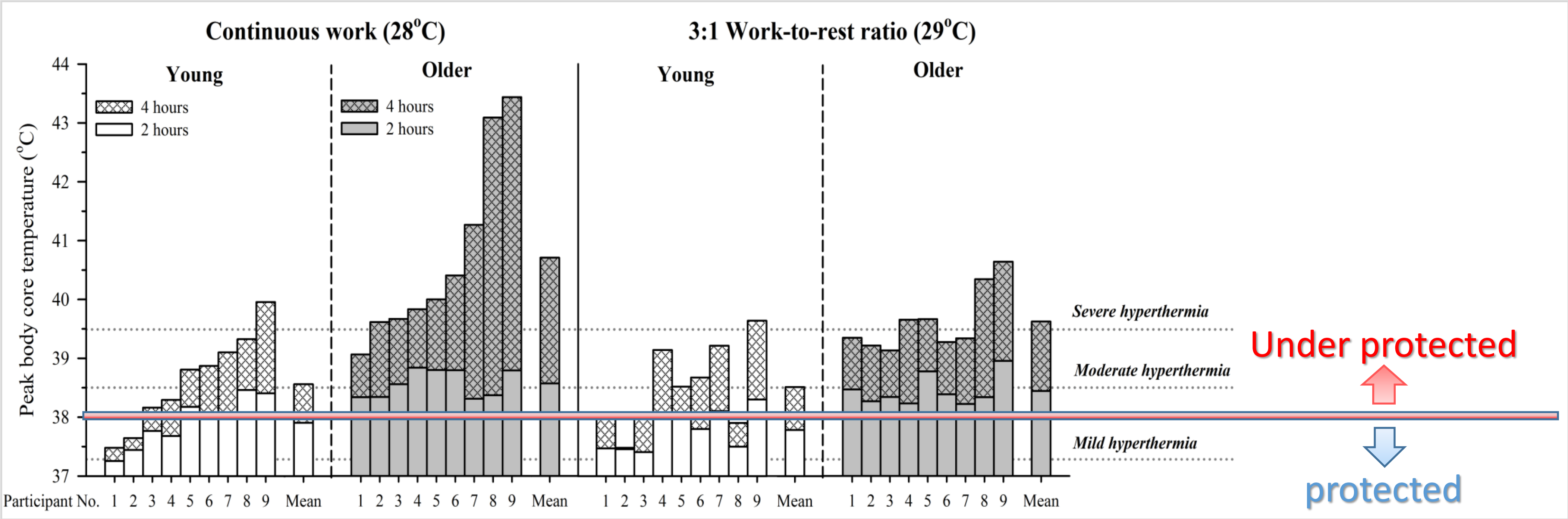
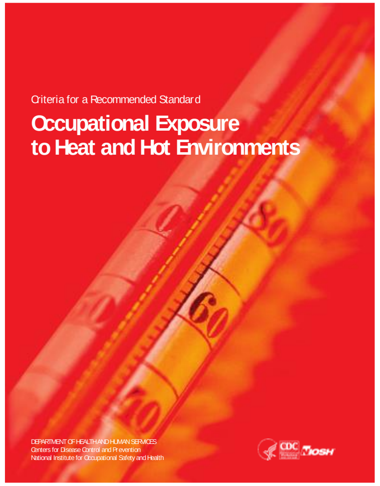
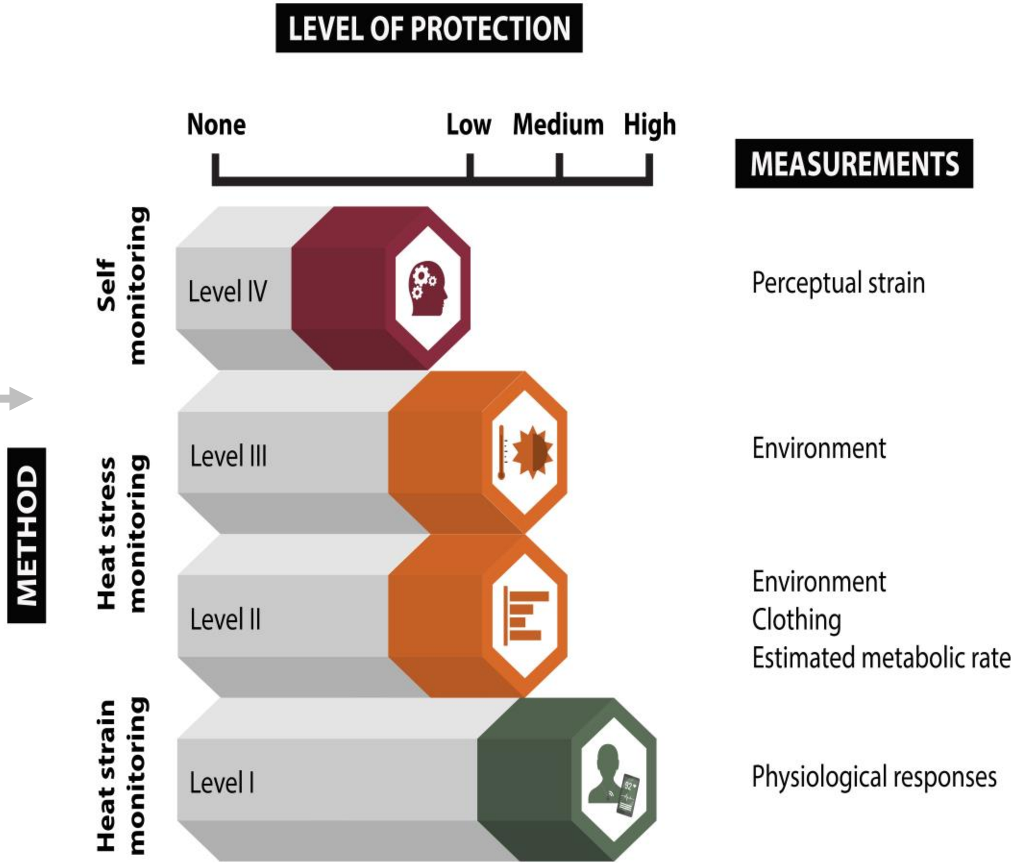


Figure. Peak body core (rectal) temperature for young (n=9; 21 years; white bars) and older males (n=9; 58 years; grey bars) during a work simulation in accordance with the ACGIH TLV® guidelines for moderate-to-heavy intensity work (typical of the average work effort in many mining jobs) in different WBGT.

J Occup Environ Hyg. 2017;14:703

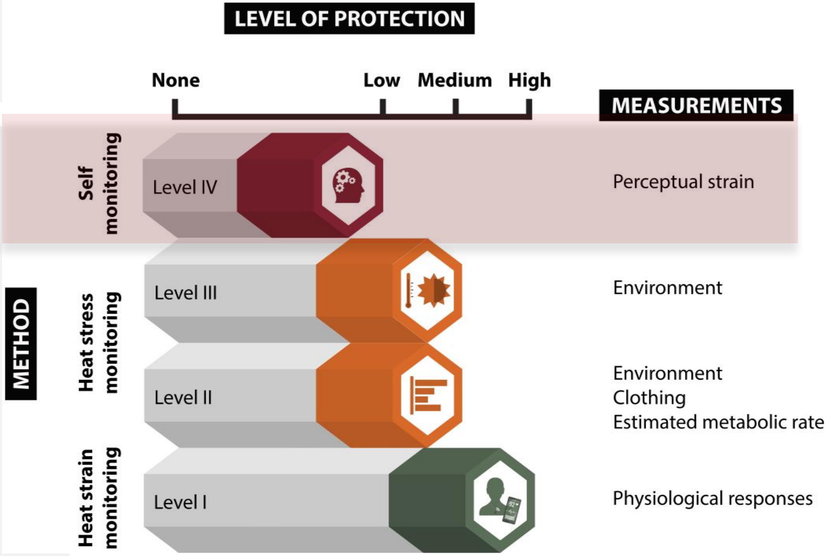


Monitoring a **workers response to heat** can dramatically reduced the risk of heat-related injuries (or death) or injuries caused by heat-induced fatigue.



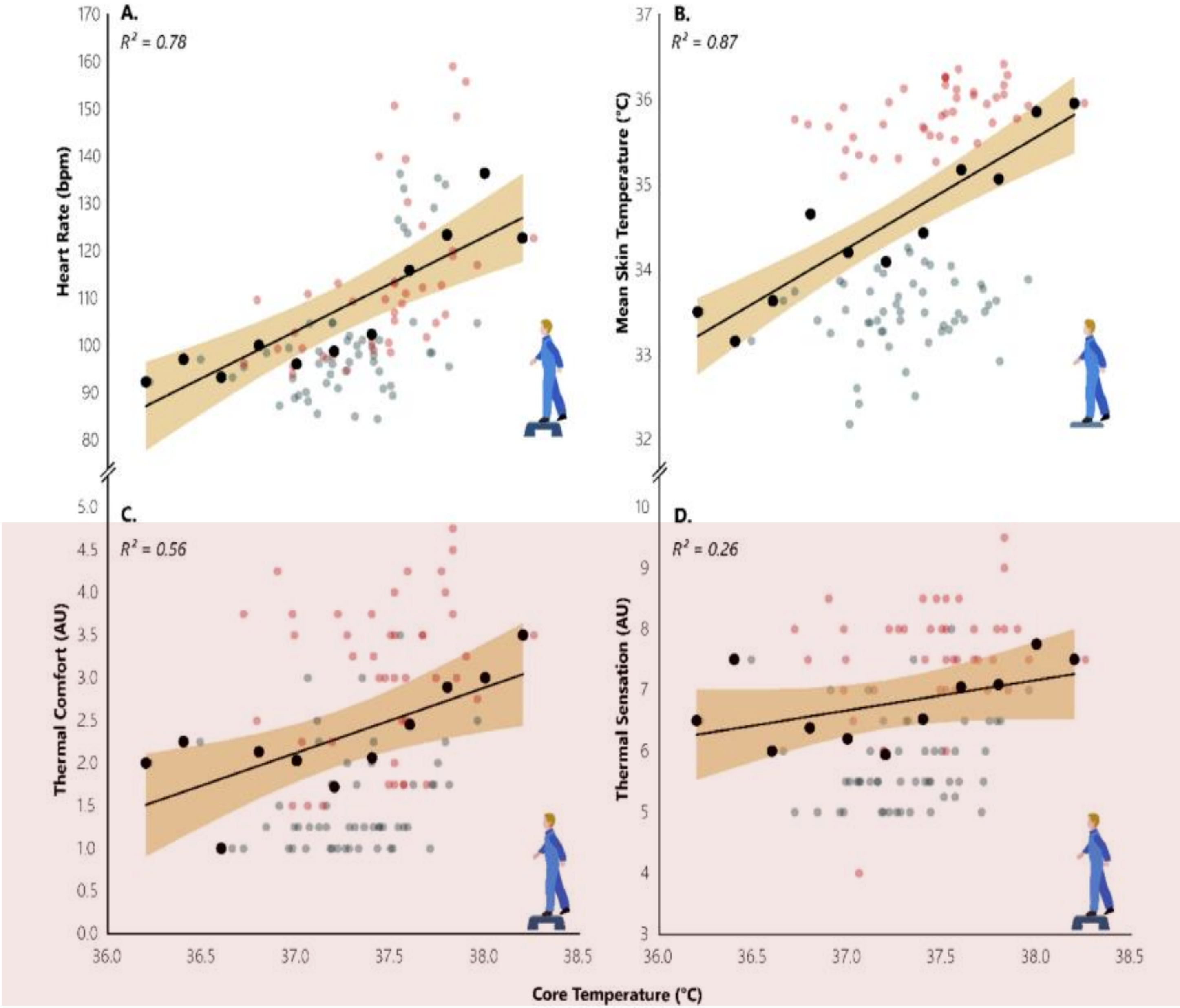
Appl Physiol Nutr Metab 2018;43:869

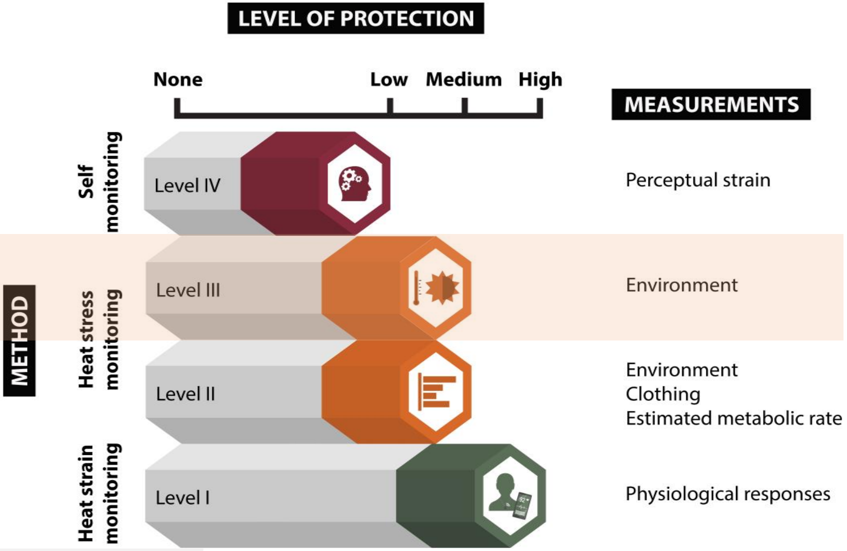
HEPRU research staff [left] assessing electric utility worker in Texas, USA (46°C, 55%RH; Core temperature: 39.6°C



Translating the science:

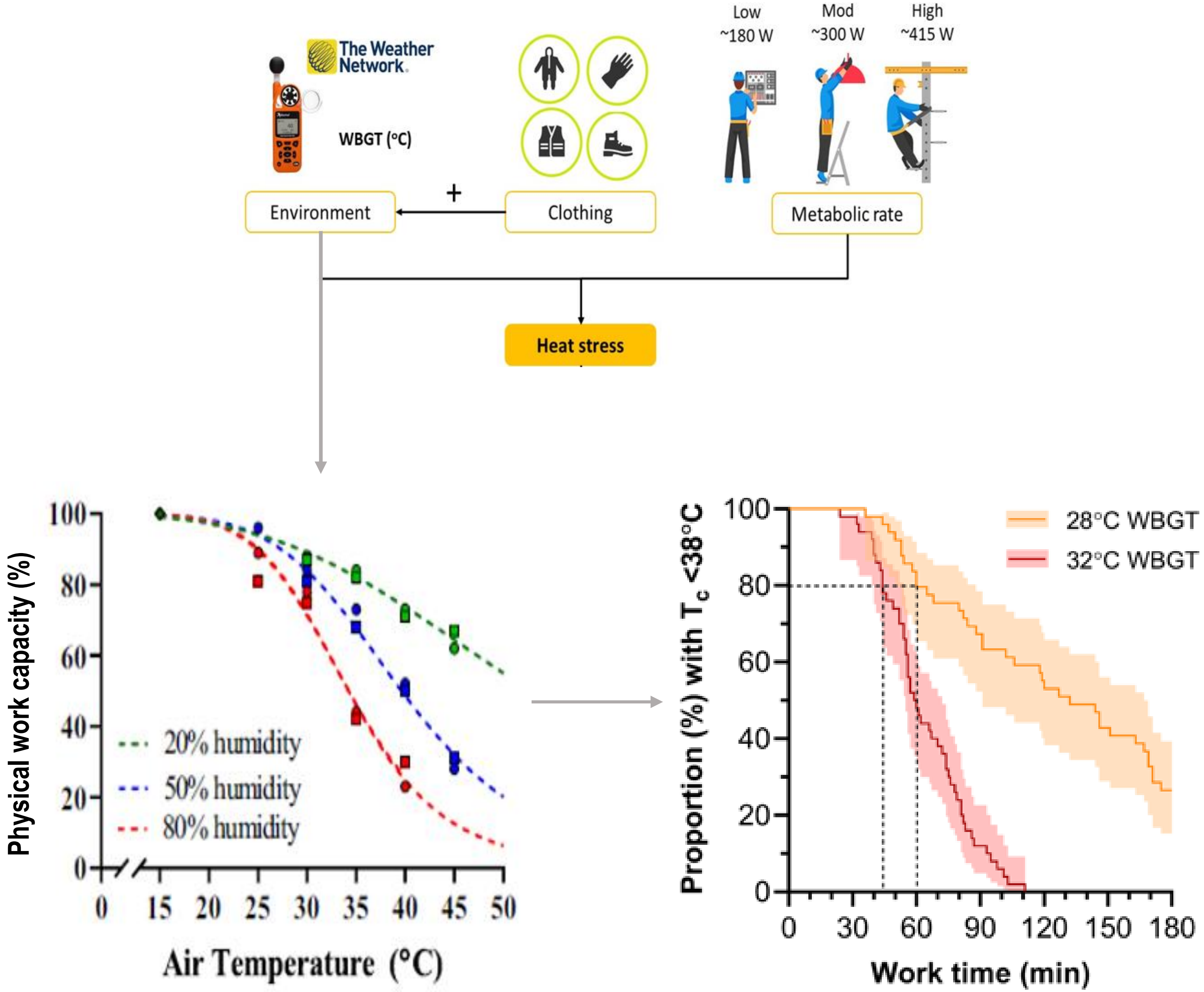
- Monitoring changes in one or more physiological variables can help you estimate a worker's level of heat strain during work in the heat.
- However, subjective measures underestimates a workers level of heat strain.

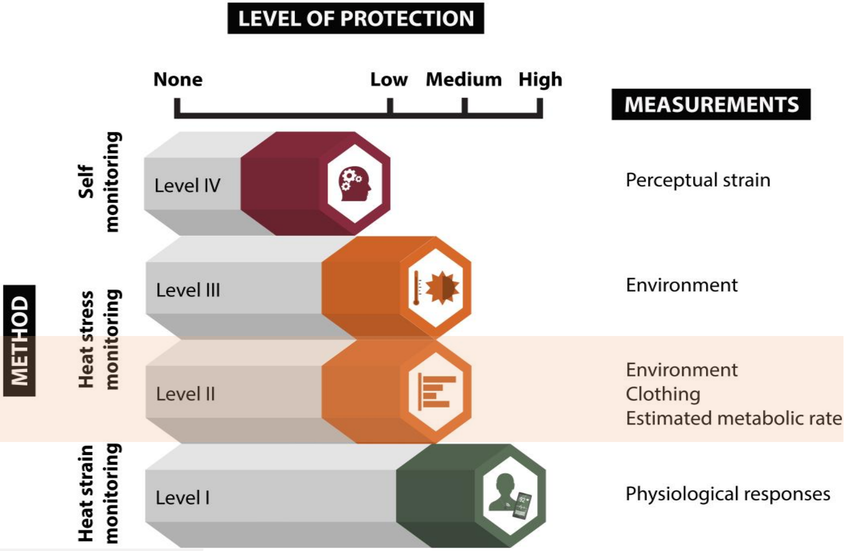


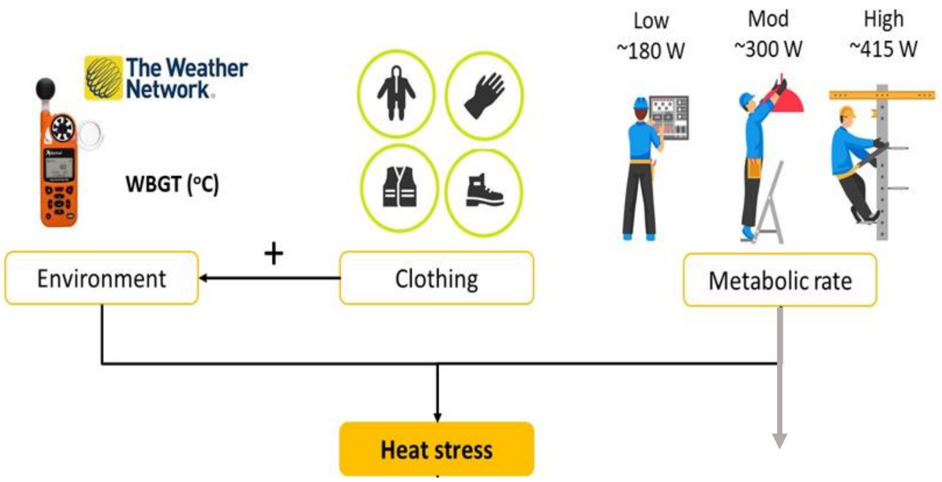


Translating the science:

- Monitoring local environmental conditions is critical.
- There exists significant variability in safe work times amongst workers within a given environment.



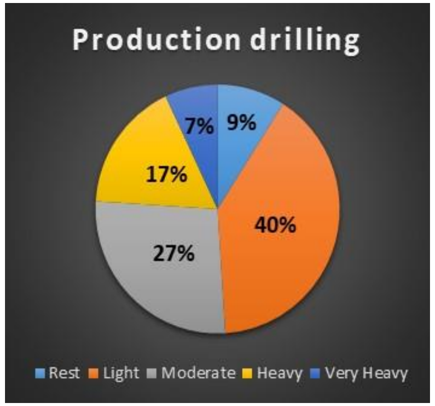


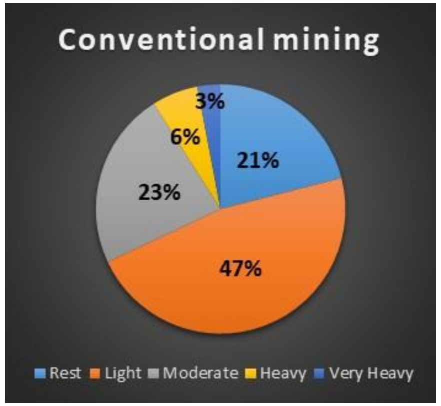


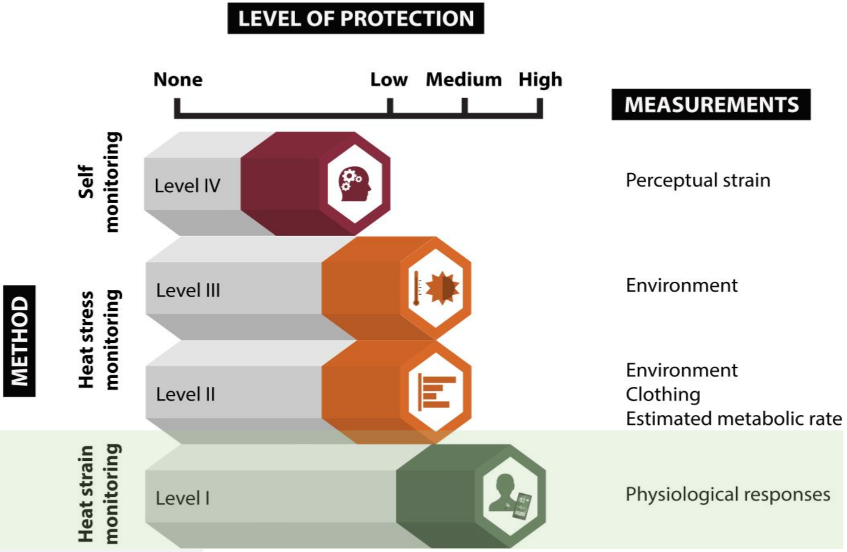
Translating the science:

- Understanding the work demands is critical to defining safe work times
- Time-weighted averaging is appropriate for quantifying the metabolic demands of variable-intensity work to assess occupational heat stress.

Med Sci Sports Exerc. 2020; 52:2628



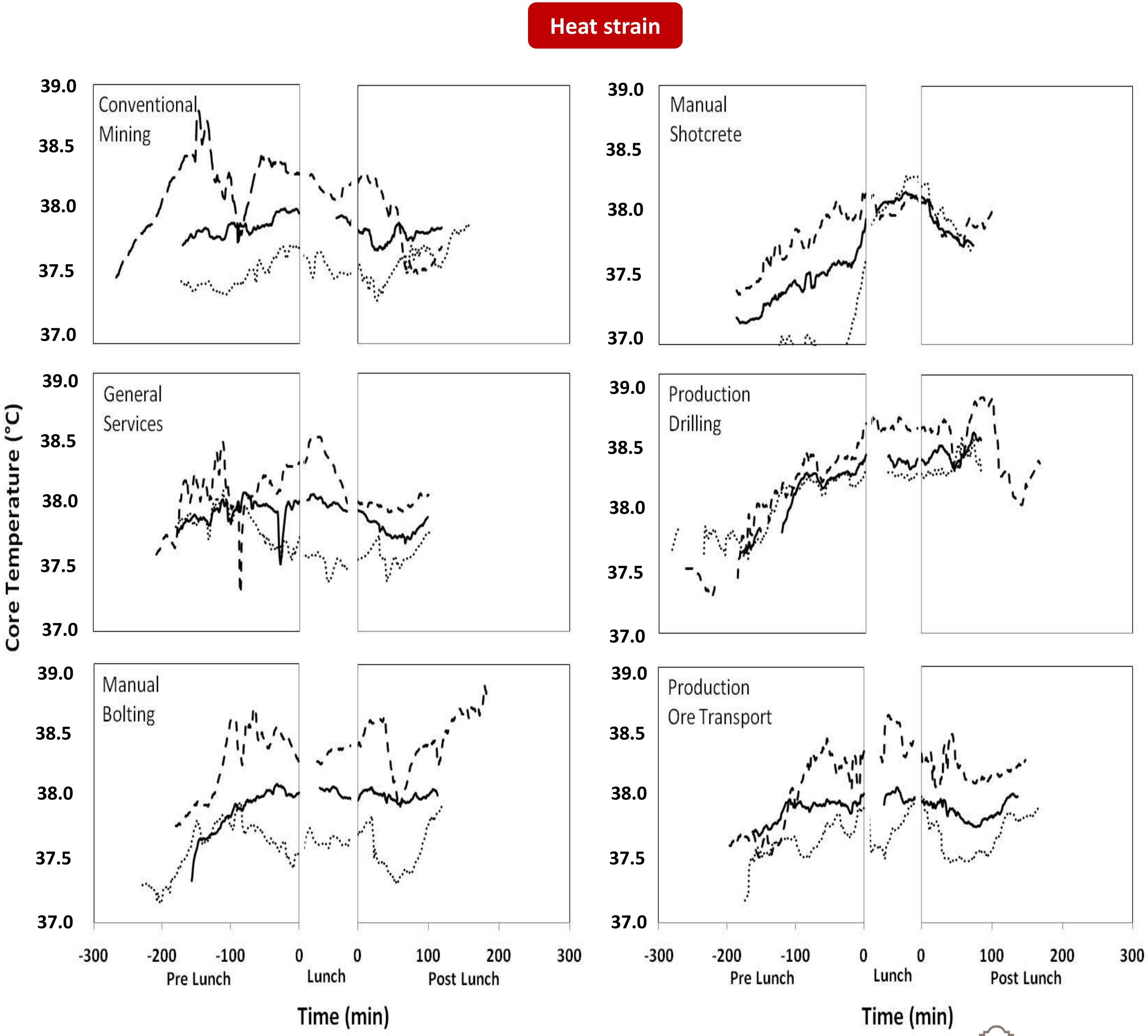




Translating the science:

- Monitoring a workers response to heat can dramatically reduced the risk of heat-related injuries caused by heat-induced fatigue.

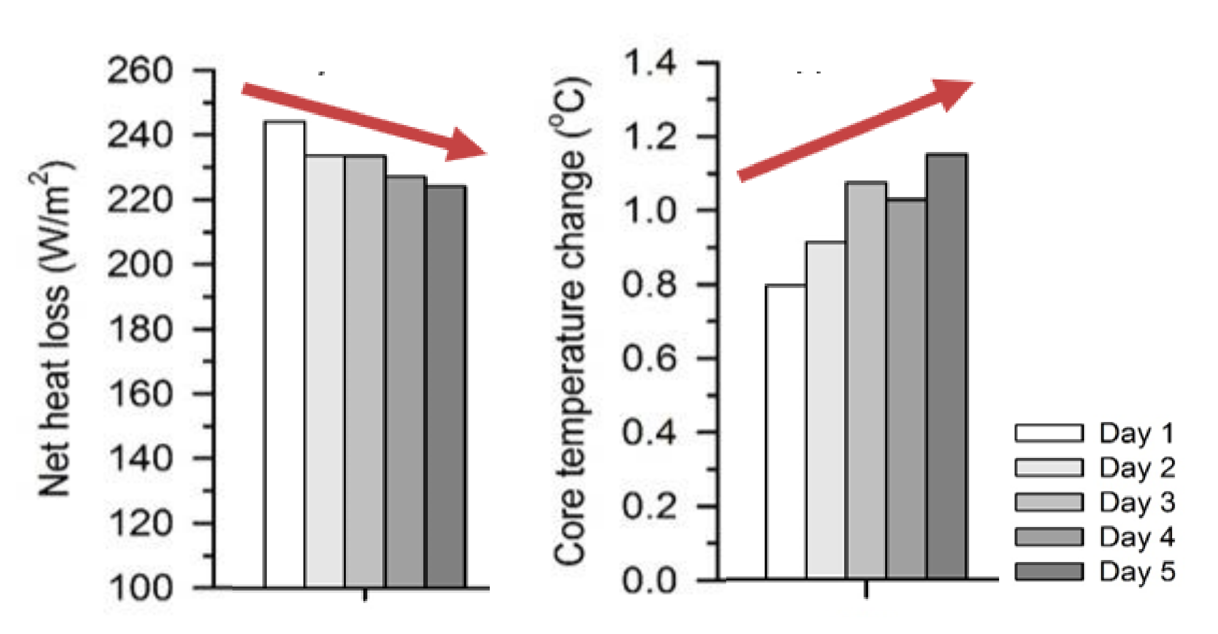
- However, there exist individual variability between individuals doing the same job, within the same environment.



The ‘hang-over’ effect of heat stress

Translating the science:

- workers experience reductions in heat dissipation and higher core temperatures for the same work performed on the next day- the ‘*hang over*’ effect.
- this response occurs even if the level of heat stress is the same and work intensity is reduced.



How can to mitigate these next-day effects?

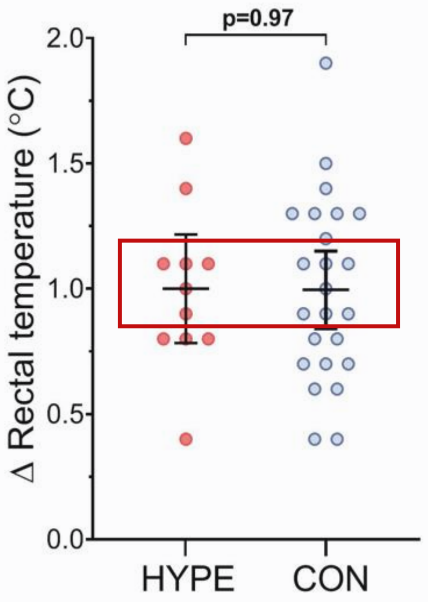
Good.

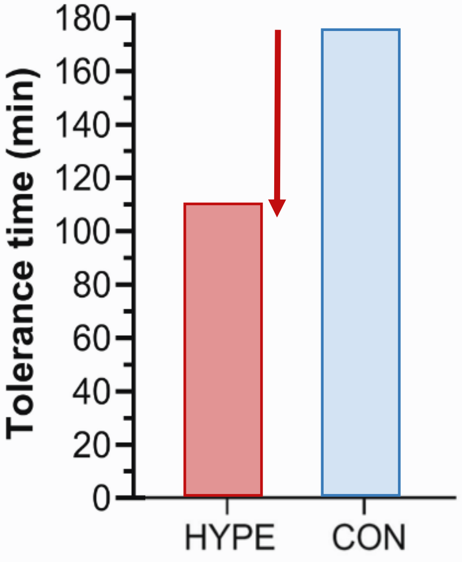
- cool down as soon as possible following a work shift.
- ensure adequate rest following a work shift (e.g., avoid strenuous exercise).
- hydrate after a work shift, even if you’re not overly thirsty .
- ensure you get adequate sleep.

Best.

- perform harder tasks at start of work week and or intersperse less intense days between workdays.
- reduce work pace by ~15% on the next day if work tasks cannot be changed.
- consider reducing shift duration over consecutive days in hot weather.

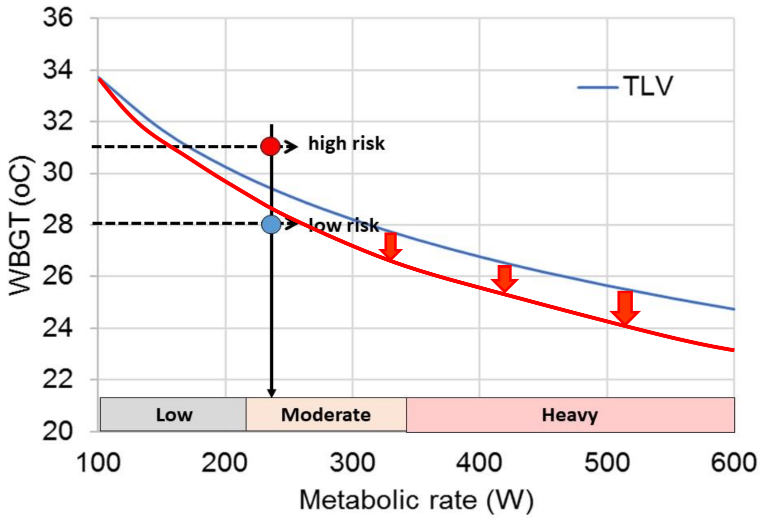
Worker with hypertension



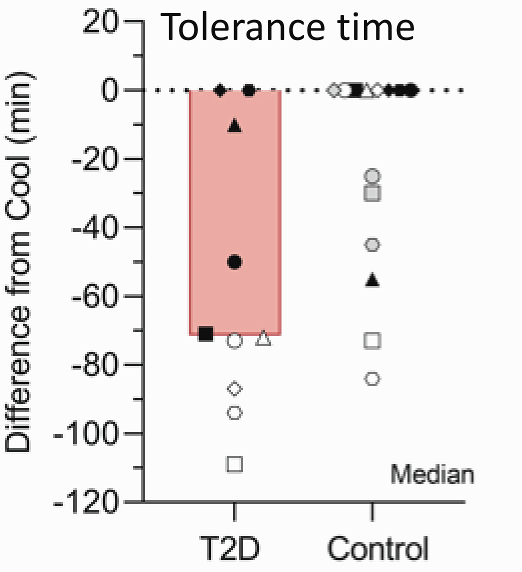


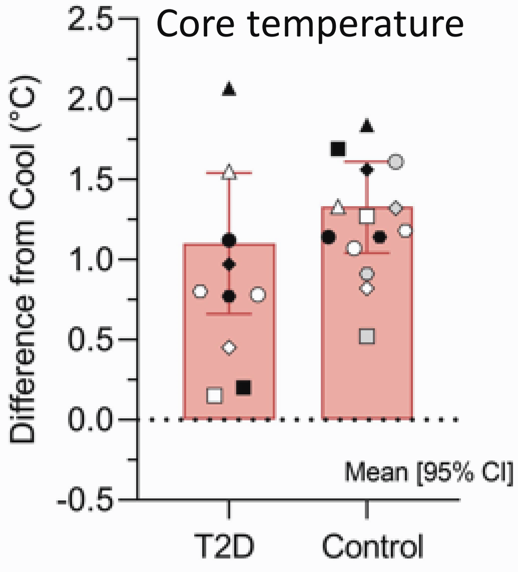
Translating the science:

- Two workers of the same age and work ability can have the same core temperature and heart rate, yet one is at a much higher risk of collapsing early during work in the heat – can you identify this person?
- Despite our ability to monitor human performance in hot environments, we are still under protecting many workers.
- Get in the know – know your worker, plan the workday.



Worker with type 2 diabetes

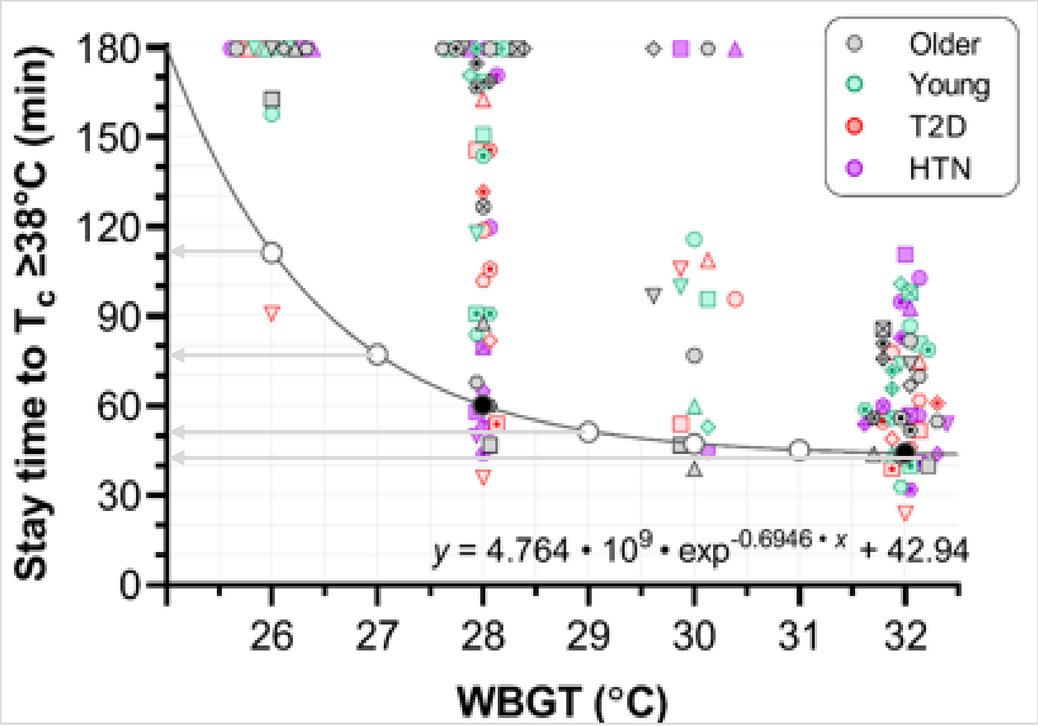




Keeping your workers safe in extreme heat with proper planning

Translating the science:

- Current work guidelines do not provide information on the safe initial work times before heat-alleviation strategies should be employed (e.g., rest breaks, cooling).
- However, a recent large scale study from our lab provides this information.

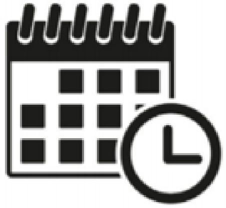


Appl Physiol Nutr Metab. 2022; 47: 110; Appl Physiol Nutr Metab. 2022;47:711

Have a plan

Watch the weather

Be prepared to reorganize your day



Key take-home message:

'*Industrial innovation was born largely from the mining sector, and history is full of noteworthy examples*' (Ontario Mining Association).

However, there remains significant shortcomings of current heat management guidelines that continue to compromise the health and safety of workers who must perform their duties in the hot environments.

With climate change fueling an increase in the occurrence of hot weather, the risk of heat-related injury and disease is expected to rise dramatically over the next decades. With the support of research, the mining sector is well positioned to lead the charge in creating innovative ways to protect workers.

The Human and Environmental Physiology Research Unit (HEPRU)

Home of Operation Heat Shield Canada

Together….Creating Heat-Resilient Workforce

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Questions?

Heat indices in mines

Date	Index	Notes
1916	Kata thermometer (K)	Used in the gold mining industry in South Africa to express the cooling power of air ([18])
1923	Effective temperature (ET)	First used in South Africa. Further developed on the basis of subjective comparisons between climates by sedentary subjects. Widely used in the mining industry in Britain, Germany, Belgium, and France [19]
1947	Predicted four hour sweat rate (P4SR)	Applied in hot underground mines in the tropics of northern Australia [20].
1957	Wet bulb globe temperature (WBGT)	The most used widely index for underground mines because of its simplicity [21]. Has been used in research to see the effect of the operating equipment, such as in a potash mine in Saskatchewan, Canada [22]. Also used in field studies to evaluate the physiological demands at the Agnico-Eagle's Laronde mine in Preissac, Quebec [23], and the hydration status in underground miners in the tropics of northern Australia [20]
1957	Oxford index (WD)	The Oxford index was invented in 1957 by Lind and Hellon and based on the wet bulb temperature (*Tw*) and dry bulb temperature (*Ta*) [24] [25]. The Oxford index is not appropriate to use in cases where the radiation factor is important. Has been widely applied in mine rescue to calculate the tolerance time [19]
1971	New effective temperature (ET*)	Proposed by Gagge et al. [26]. Applicable over a wide range of climate situations, although too difficult to apply on a daily basis
1971	Wet globe temperature (WGT)	Highly correlated with the WBGT for moderate heat and humidity conditions; however, this relationship is not constant for all environmental factors [1]. Widely used in surface and underground mines
1972	Basic effective temperature (BET) or ET(A)	More suitable for underground mine conditions. Largely used in the coal mining industry for longwall operations in Australia [27] and the UK and Europe in coal and potash mines [15]
1979	Humidex	The humidex index was created in 1979 by the Atmospheric Environment Service of Canada to quantify the body sensations of a person in high temperature and humid conditions. Humidex has been used in hot open pit mines in Tehran Province, Iran. Studies show that humidex is more valid than effective temperature (ET) and discomfort index (DI) and is low cost and user friendly for interpretation [28]. Also, humidex performs better in hot conditions with humidity such as hot underground mines [29]

Heat indices in mines - continued

1996	Cumulative heat strain index (CHSI)	The first version of the heat stress index (HIS) was released in 1955, applicable to standard workers (not using heavy clothing) and without high heat stress conditions [30]. The HIS was corrected in 1966 by refining equations with exponents and coefficients [31]. The HSI monograph simplifies the use of the index analyzing the heat stress factors [1]. The HSI index was used in mines in Tehran, Iran [28]. The CHSI appeared in 1996, as an assessment to predict the heat strain during heat exercise test in terms of core temperature and heat rate [32]
1998	Modified discomfort index (MDI)	The MDI is a simple tool to measure the heat load [33] and can replace the WBGT at certain latitudes [34]. MDI is applied in the control of Australian bushfires, ensuring a safe environment in the shelters [35]
2001	Predicted heat strain (PHS)	The second most widely used index in mines, the PHS index is based in the standard ISO 7933:2004: ergonomics of the thermal environment is used to evaluate heat stress in terms of high core temperatures or increasing water loss. PHS predicts the maximum allowable exposure times. This index has been used in China's coal mining industry to study the heat stress in miners in a movable refuge chamber [36], and studies of miners using shorts and normal mining clothing in hot underground coal mines in China (Jiansong [37])
2002	Thermal work limit (TWL)	Widespread adoption in underground Australian mining. TWL has been proven to perform better than WBGT in outdoor work environments [38]
2005	Wet bulb dry temperature (WBDT)	Created in 2005 using the results of cumulative daily average WBGT index to detect heat stress risk [39]
2012	Universal thermal climate index (UTCI)	The UTCI was established by the International Society of Biometeorology [40]. This index has been well-accepted in the industry because it more precisely represents human biothermal conditions [41]. The UTCI index has been used in mines in Tehran, Iran [28]