SOURCE ENDURANCE the science of results

Athletic Performance Optimization in Hot Environments

Adam Mills, MSEd, RCEP
Source Endurance

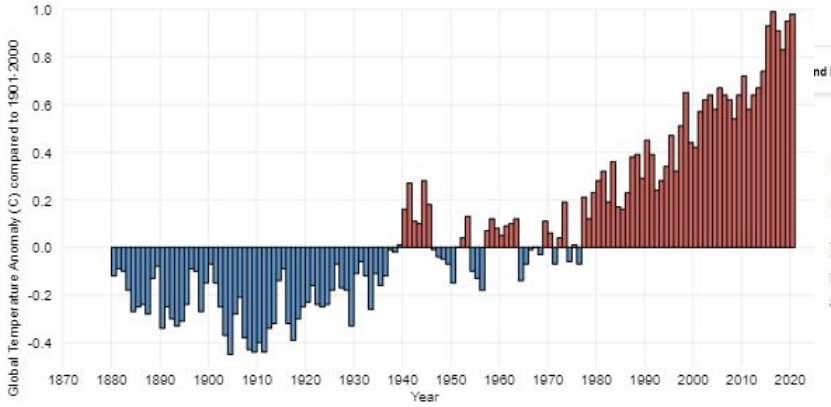
The New York Times

'Carri Richardson Suspension | U.S. Gymnastics Team | Some Protests Allowed | Olympics Guide

Tokyo Braces for the Hottest Olympics Ever

In 1964, the Tokyo Olympics were held in October. There was a reason for that. It was hot then. It's hotter now.

History of global surface temperature since 1880



Idaho Statesman

WEATHER NEWS

When will it end? Idaho heat wave to produce many more 100-degree days in Boise

BY IAN MAX STEVENSON

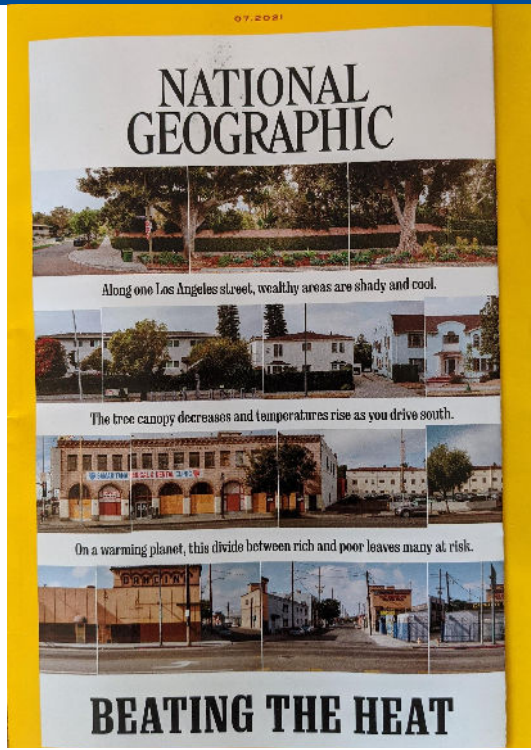
JULY 02, 2021 04:00 AM

The New York Times

nd Environment › | Infrastructure Deal | Native Americans and Climate | Wildfires and Water Supply

Climate Change Is Making It Harder for Campers to Beat the Heat

Burn bans, flashlight campfires, extreme heat and stronger rainstorms: Today's campers are experiencing their summer fun against the backdrop of climate change.



Athletic Performance in hot environments

- What is a hot environment?
- How does it affect performance?
- Physiological adaptations

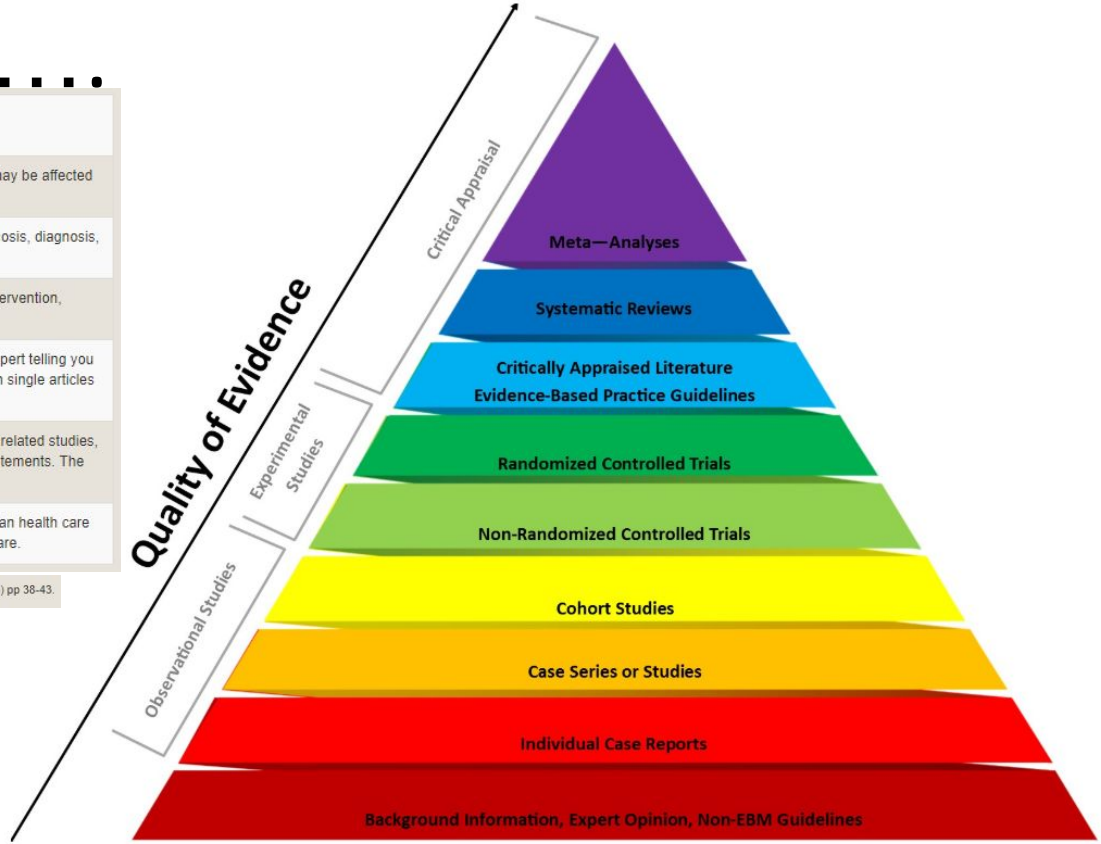
 -Improved performance in hot conditions

- Close the Research to Practice Gap Evidence based Practice to help you at home

But first….

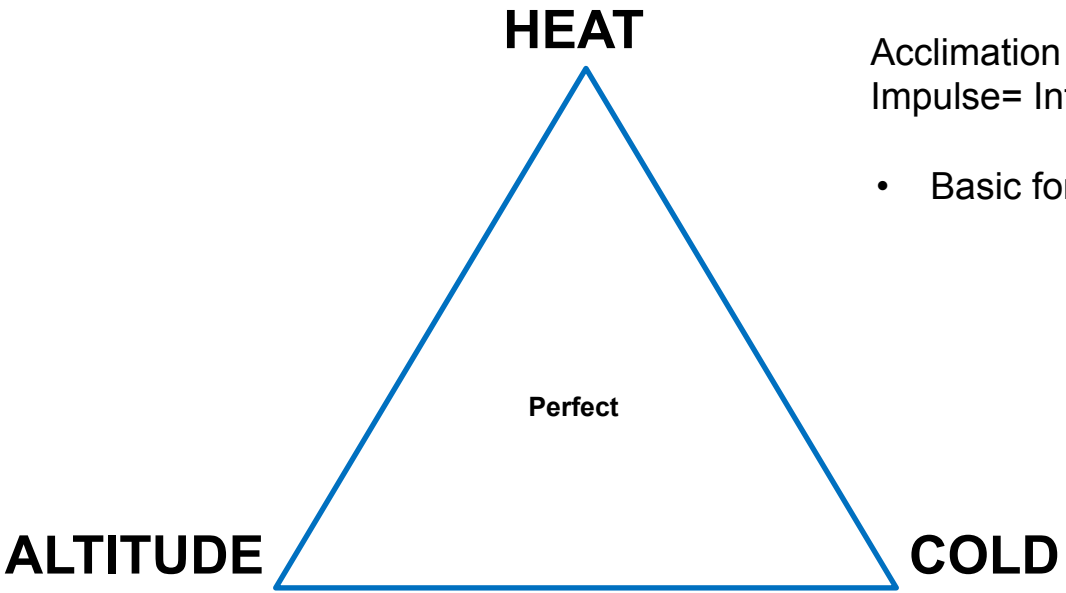
Ideas, Opinions, Editorials, Anecdotes	Least reliable. Basically anecdotal. Unscientific reports and observations
Case Series and Case Reports	Slightly more reliable but there is a potential for bias in recalling information and the quality may be affected if the information is collected retrospectively
Cohort Studies	Becoming more reliable. Observational studies are good at answering questions about prognosis, diagnosis, frequency and aetiology but not questions regarding the effect of an intervention
Random Control Trials	Very Reliable/ Gold Standard. Random Controlled Trials are able to quantify the effects of intervention, hence they are higher up the pyramid than Cohort Studies
Critically-Appraised Individual Articles (Article Synopses)	Increasing reliability of findings. A synopses is the evidence of an individual article with an expert telling you its strengths. This is less reliable than Critically Appraised Topics as there is less evidence on single articles than in a synthesis of the topic using several papers.
Critically Appraised Topics (Evidence Syntheses)	Very high reliability. Synthesising research publications entails the categorising of a series of related studies, analysing and interpreting their findings and then summarising those findings in to unified statements. The potential lack of standardisation can undermine the validity.
Systematic Reviews and Meta-analysis	The most reliable of all. Systematic reviews and Meta analyses of primary research into human health care and health policy are recognised internationally as the highest standard in evidence-based care.

Source: Ingham-Broomfield, R. (2016). A nurses' guide to the hierarchy of research designs and evidence. *The Australian Journal of Advanced Nursing*, 33 (3) pp 38-43.



The above image is based on the EBM Page Generator (2006) from Dartmouth College and Yale University and the Coursera MOOC "Understanding Clinical Research: Behind the Statistics" (2016).

Extreme Environment as a Physical Stressor



Acclimation is a product of:
Impulse= Intensity x Duration

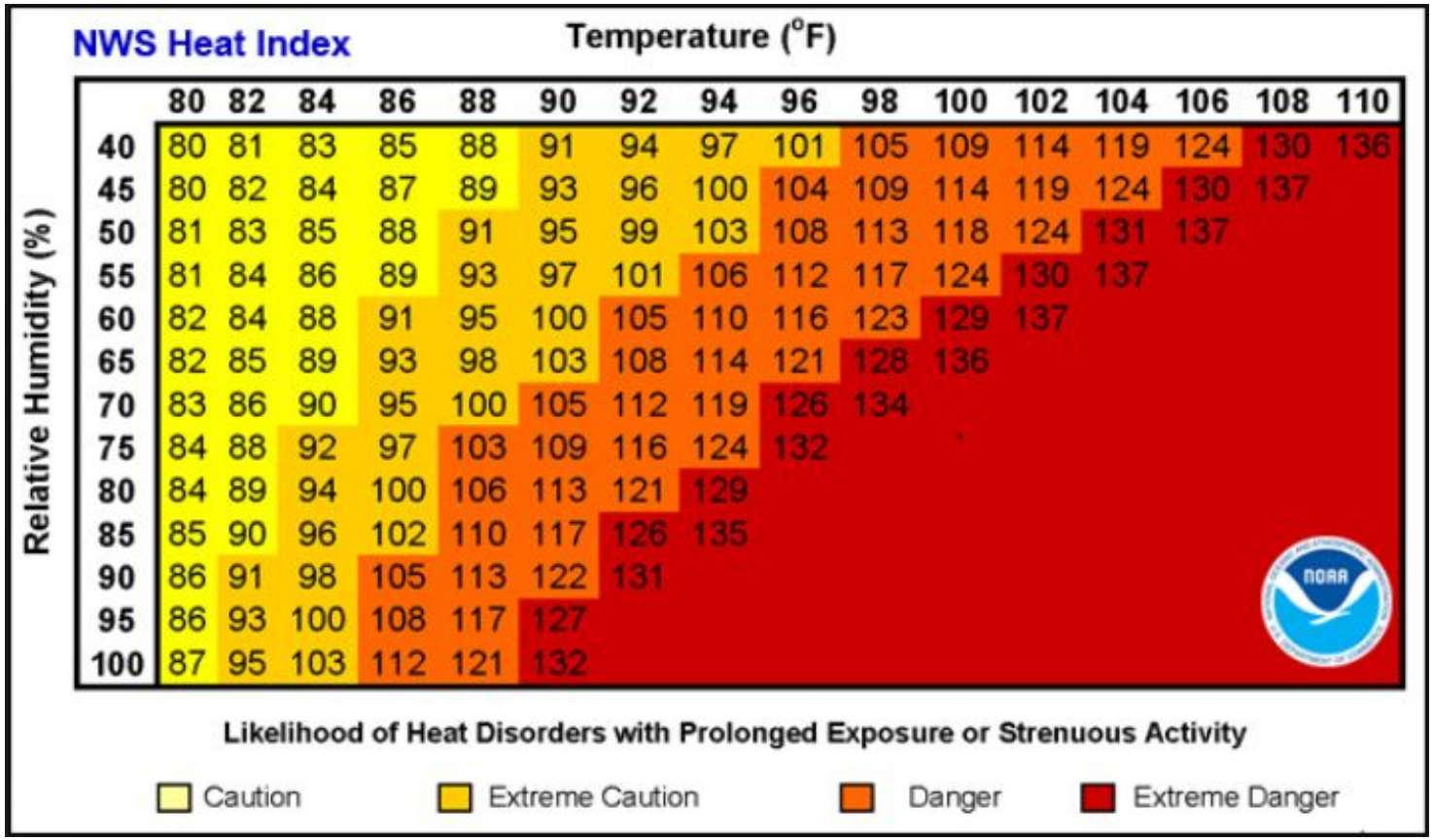
- Basic formula for training

What is a hot/ extreme environment?

Combination of conditions that present an added heat stress on the body. Extreme heat stress can overwhelm the body's coping mechanisms and lead to a variety of serious conditions.

- "Real Feel" of 91F (extreme caution) >30C + 60% humidity
- Air temperature
- Humidity
- Solar radiation (sunny or cloudy), air movement

Hot Environment as a continuum



Negative impact of heat on performance

Degradation of performance is rooted in core temperature

- Dissipation of heat is paramount to maintaining performance in hot weather.
- Humans are only 20% efficient, meaning 80% of energy we use is lost as heat.

When core temp begins to rise…

- Central Nervous System
  - Multiple changes that occur in an overheated brain.
  - Alter brain function- “safety brake” + slow reactions+ poor decision
- Cardiovascular function
  - Increases blood demands everywhere
    - Skin, Muscles compete heavily for blood.
      - When plasma volume drops, compromises are made

Negative impact of heat

Muscle function- Fatigue more quickly

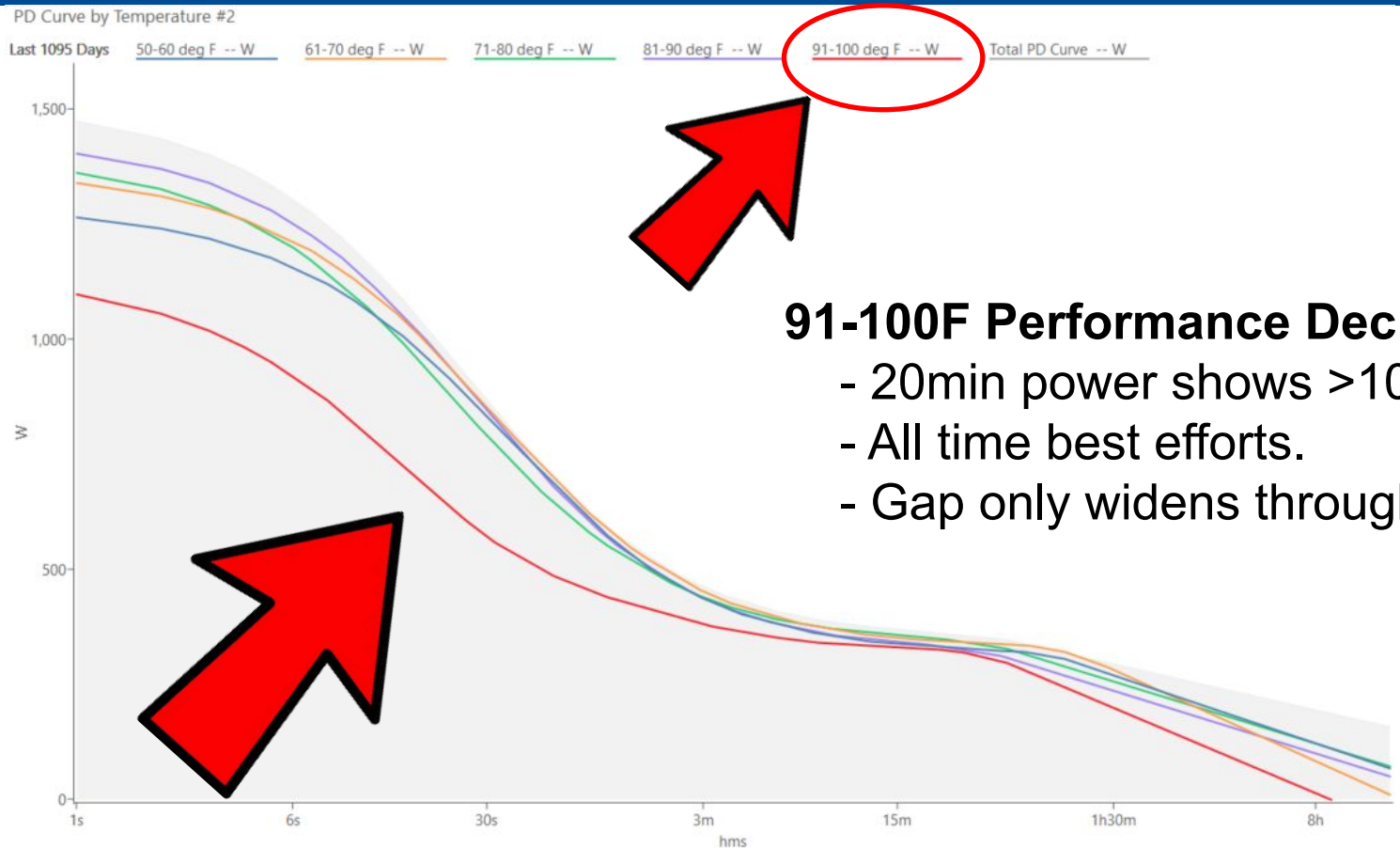
- Increase in Glycogen breakdown+ accumulation of metabolites
- Hyperthermia from environment will reduce time to exhaustion
- Hyperthermia from environment reduces muscular force generation, PNS

  - Different from “warm up” -heat from exercise improves muscle function

Performance when dehydrated

–2-4% loss of body mass to dehydration

- 6-16% loss of Vo2 max, or more



91-100F Performance Decline:

- 20min power shows >10% drop
- All time best efforts.
- Gap only widens throughout a session

Heat- Related Illness

Heat Exhaustion

WHAT TO LOOK FOR

- Heavy sweating
- Cold, pale, and clammy skin
- Fast, weak pulse
- Nausea or vomiting
- Muscle cramps
- Tiredness or weakness
- Dizziness
- Headache
- Fainting (passing out)

WHAT TO DO

- Move to a cool place
- Loosen your clothes
- Put cool, wet cloths on your body or take a cool bath
- Sip water

Get medical help right away if:

- You are throwing up
- Your symptoms get worse
- Your symptoms last longer than 1 hour

Heat-Related Illnesses

Heat Stroke

WHAT TO LOOK FOR

- High body temperature (103°F or higher)
- Hot, red, dry, or damp skin
- Fast, strong pulse
- Headache
- Dizziness
- Nausea
- Confusion
- Losing consciousness (passing out)

WHAT TO DO

- Call 911 right away-heat stroke is a medical emergency
- Move the person to a cooler place
- Help lower the person's temperature with cool cloths or a cool bath
- Do not give the person anything to drink

Benefits of Adaptation

Very possible and effective.

However…

All adaptations to the heat are predicated by an increased ability for your body to more effectively thermoregulate. This is primarily accomplished through increased sweating. HYDRATE!

Benefits of Adaptation

All adaptations to the heat are predicated by an increased ability for your body to more effectively thermoregulate. This is primarily accomplished through increased sweating. HYDRATE!

Benefits of Adaptation

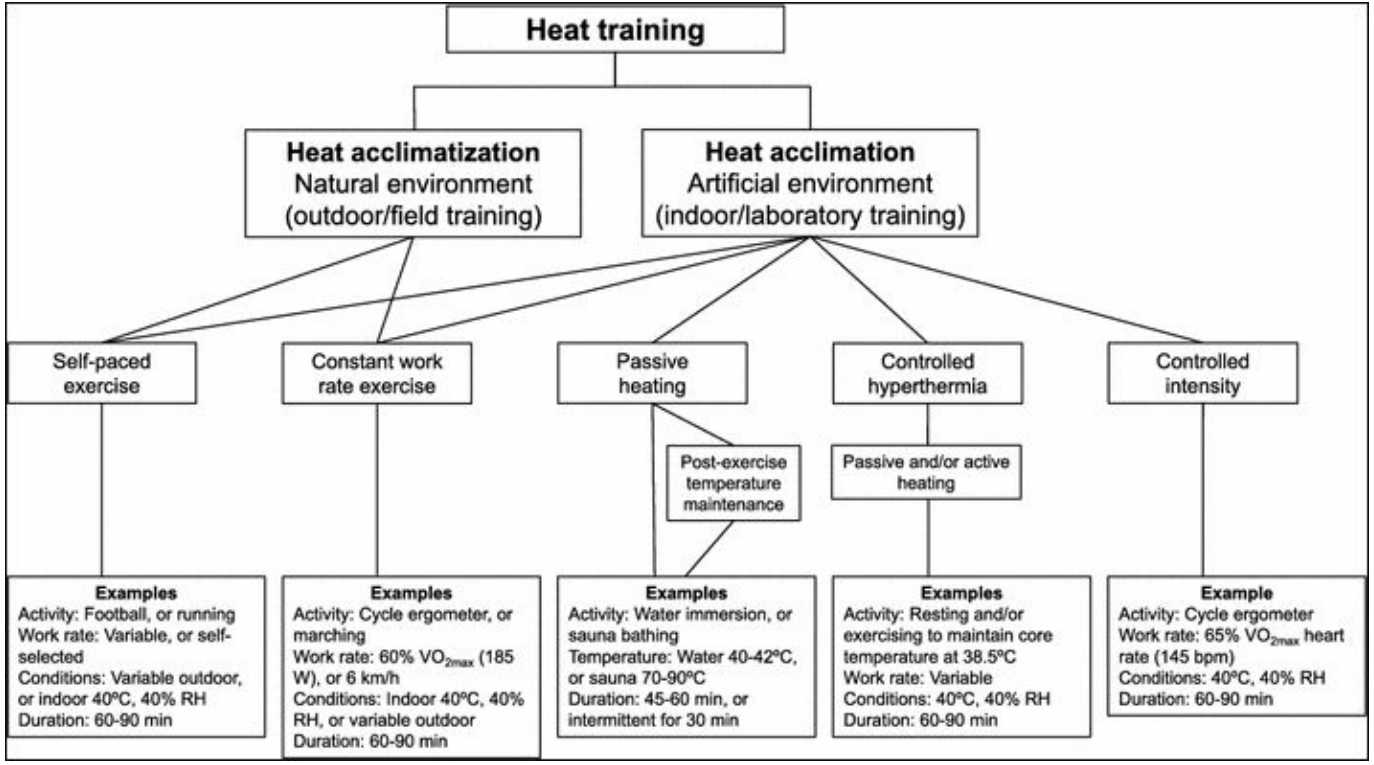
- Body is able to more effectively regulate core temperature through sweating and evaporative cooling. Dry and breezy conditions are ideal for this mechanism.
- Core Temperature at rest and during exercise: DECREASED
- Sweating: trigger, rate, sensitivity: IMPROVED (1L/hr +2L/ hr)
- Skin Temp: REDUCED
- Skin blood flow: INCREASED
- Fluid Balance: thirst: IMPROVED. Electrolyte loss: REDUCED. Plasma volume: INCREASED
- Cardiac: Output, HR, SV, efficiency: IMPROVED
- Whole body metabolism: LOWERED

Benefits of Adaptation

- Muscle Glycogen: SPARED
- Lactate Threshold (FTP): INCREASED
- Force Production: INCREASED
- Vo2 Max: INCREASED (4.6%)

- In essence, Heat Adaptation is very powerful ergogenic aid… Power Up.

Evidence Based Practice- Heat Adaptation



All of these methods have the same goal:
Increase core temp moderately to stimulate thermo-regulation (sweat) without causing heat illness.

Daanen, 2018

Evidence Based Practice- Heat Adaptation

- The training process needed to render an athlete fully heat acclimated takes time.

- It is a 14 day or more process.

- Despite the advantages *ONLY ~15% of athletes will become heat adapted*

- As we saw before there are a number of ways to execute. They all work and they all have the same fundamental goal.

- Increase core temperature, stimulate sweating, stop prior to heat illness

- Basic Formula:

Heat Adaptation= (Intensity of Heat + Exercise Intensity)x Duration x number of exposures (can me more than one per day). Exposures should not be uninterrupted

Lower heat= longer duration.

Evidence Based Practice- Heat Adaptation

General common practices:

- Once or twice daily exposure
- 40- 100 minutes each. 7-14 days
- Exercise Intensity: FTP or lower, no HIIT
- Real Feel: 91F or more (using relative humidity)

Post Exercise Hot Water Immersion

Post training, 40min @ 40C, 104F hot water immersion. 6 days.

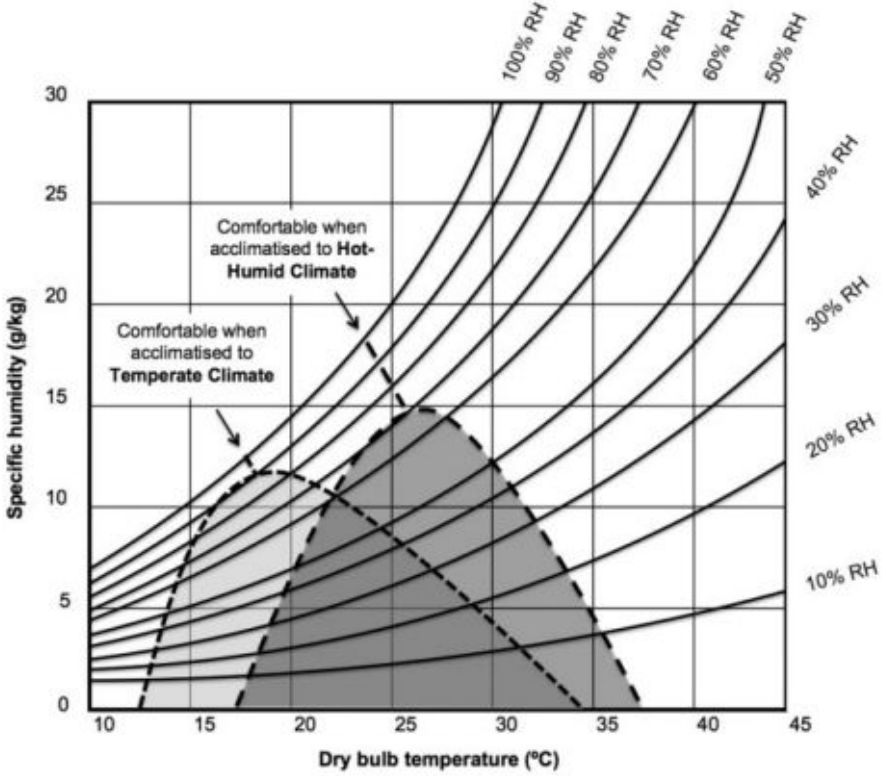
Evidence Based Practice- Heat Adaptation

General common practices:

- Using the altitude training analogy:

- Minimize exposure to air conditioning and maximize time spent in a warm/ hot ambient environment. This approach typically requires >4 hours per day for 1-2 weeks.

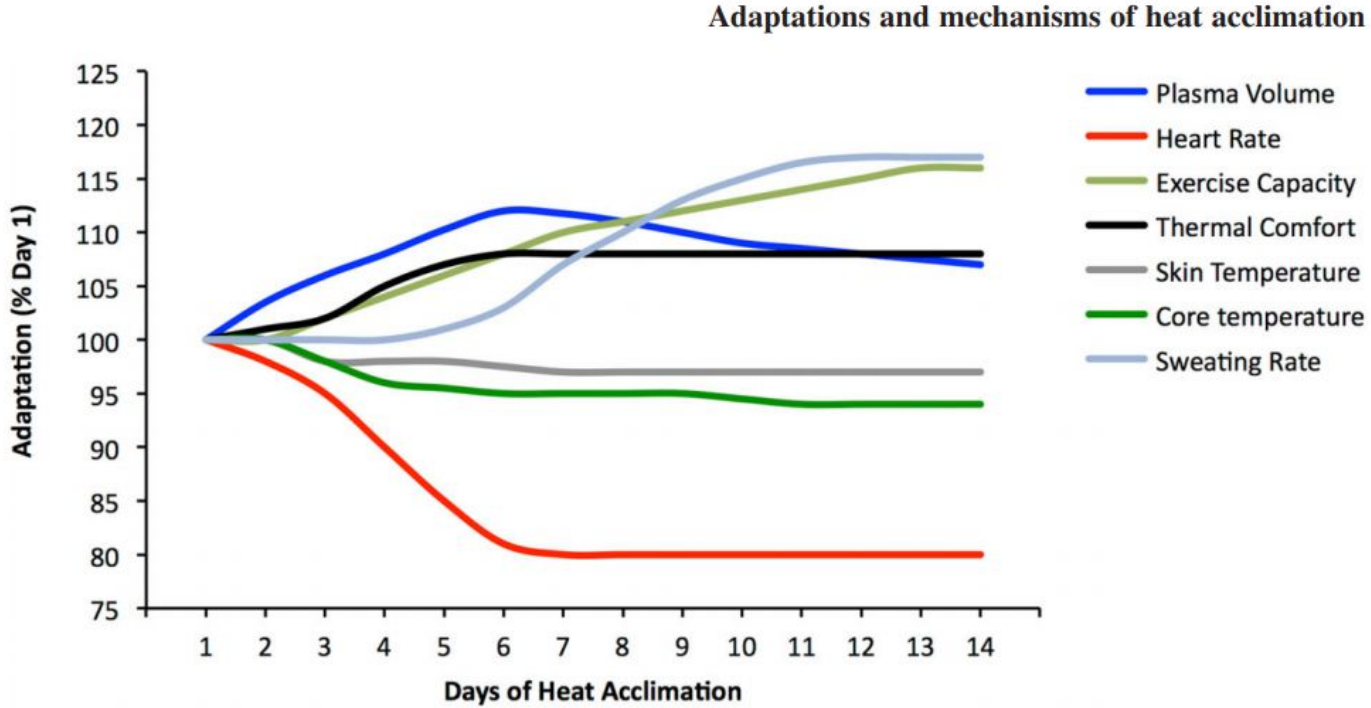
Evidence Based Practice- Heat Adaptation



Only ~15% of athletes will execute a proper heat adaptation protocol

JD Periard, S. Racinais, MN Sawka 2015

Evidence Based Practice- Heat Adaptation



PROGRESSIVE

Not much until Day 3.

Day 6: Plasma Volume

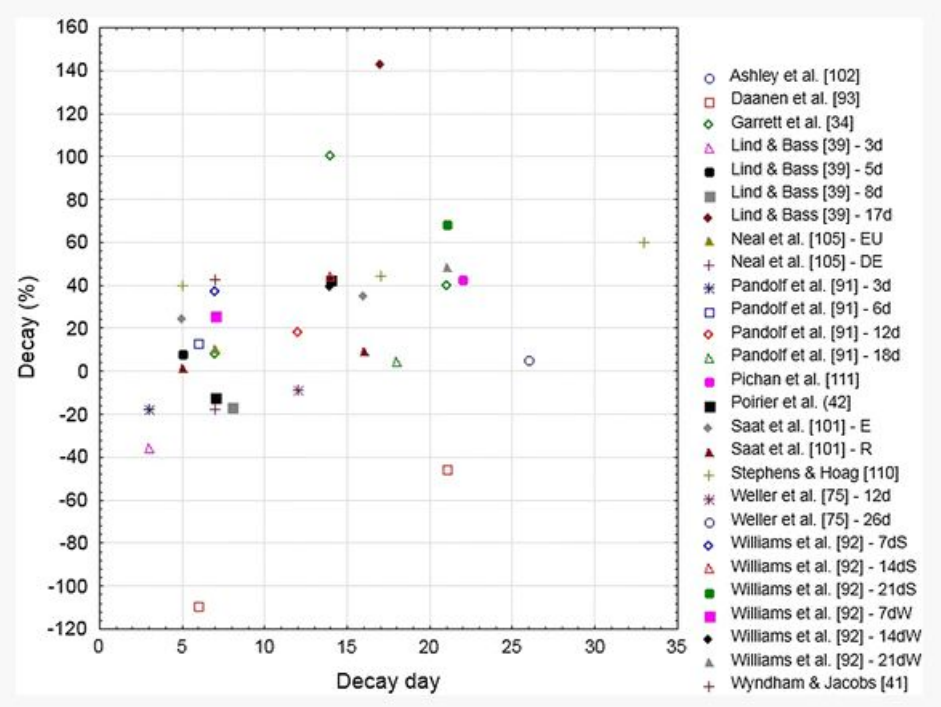
Day 11: Sweat Rate

Takes TWO WEEKS

JD Periard, S. Racinais, MN Sawka 2015

Adapting to the heat

How long are benefits maintained?



- 2.5% loss of heat adaptation per day of non- heat exposure

Daanen 2018

Evidence Based Practice- Heat Adaptation

Strategy vs tactic

- Ultimate goal is to maintain core temperature as close to normal as possible regardless of conditions
- Multiple actions, no one thing will be crucial
- Taken together, the sum of their effect is substantial

- Hydrate!

Evidence Based Practice- Heat Adaptation

Pre-competition (minimizing exposure to heat stress) (Assuming heat adapted)

- Stay in air conditioning
- Take extra care to stay hydrated
  - Begins 2-3 days before competition
- Morning pre-competition rides completed before temperatures become elevated/extreme

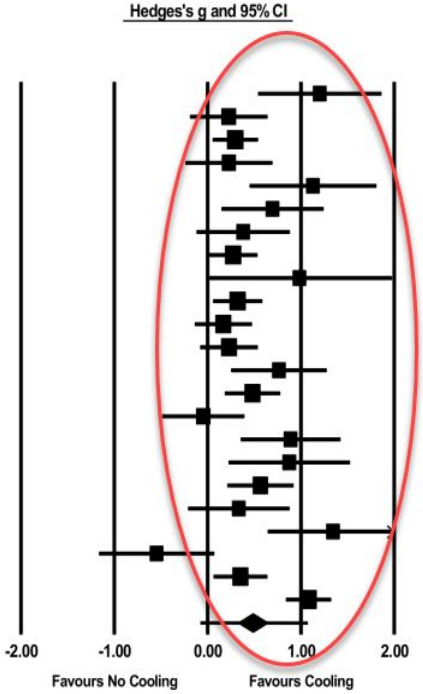
Evidence Based Practice- Heat Adaptation

E. Hohenauer *et al.*

Pre Cooling

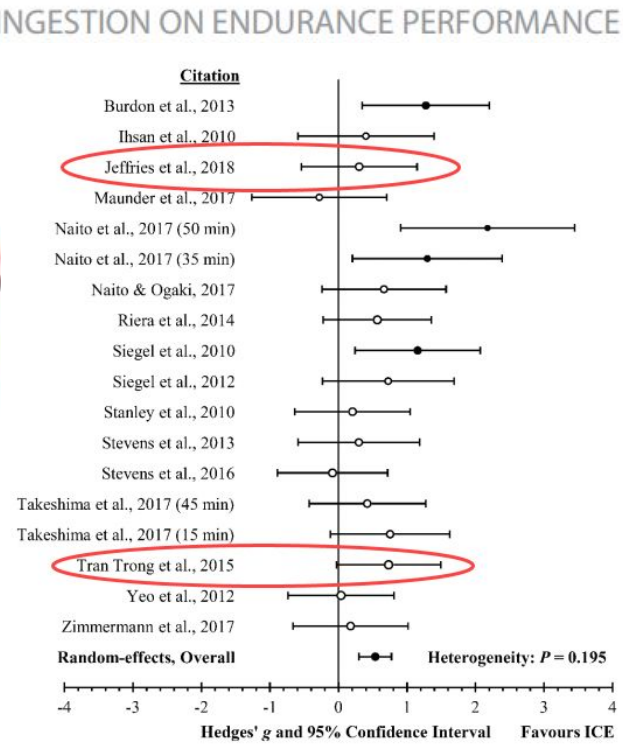
- Meta-analysis of 21 studies shows that pre-cooling helps preserve hot weather performance.
- Most studies were cycling. Some running.
- Ingesting cold water, ice slurry, ice packs
- Limited to shorter (<60min) events

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study						
Bogerd et al., 2010	1.202	0.337	0.113	0.542	1.862	3.569	0.000
Brade et al., 2014	0.226	0.211	0.045	-0.188	0.640	1.071	0.284
Castle et al., 2006	0.297	0.123	0.015	0.056	0.538	2.413	0.016
Duffield et al., 2007	0.228	0.237	0.056	-0.236	0.693	0.963	0.335
Duffield et al., 2009	1.129	0.346	0.119	0.452	1.806	3.267	0.001
Duffield et al., 2010	0.696	0.278	0.077	0.151	1.242	2.502	0.012
Duffield et al., 2011	0.382	0.254	0.065	-0.117	0.881	1.501	0.133
Faulkner et al., 2015	0.274	0.132	0.017	0.015	0.533	2.070	0.038
Galoza et al., 2011	0.984	0.504	0.254	-0.003	1.971	1.954	0.051
Gonzales et al., 2014	0.322	0.133	0.018	0.061	0.584	2.419	0.016
James et al., 2015_High intensity	0.168	0.155	0.024	-0.136	0.473	1.085	0.278
James et al., 2015_Low intensity	0.230	0.157	0.025	-0.077	0.537	1.467	0.142
Minett et al., 2011	0.764	0.260	0.068	0.254	1.274	2.938	0.003
Minett et al., 2012a	0.481	0.150	0.023	0.186	0.776	3.198	0.001
Minett et al., 2012b	-0.046	0.224	0.050	-0.485	0.393	-0.206	0.837
Morrison et al., 2014	0.889	0.272	0.074	0.356	1.421	3.270	0.001
Quod et al., 2008	0.876	0.331	0.109	0.228	1.524	2.650	0.008
Randall et al., 2015_packs	0.566	0.180	0.032	0.213	0.919	3.143	0.002
Randall et al., 2015_vests	0.334	0.277	0.076	-0.208	0.876	1.209	0.227
Siegel et al., 2011	1.345	0.356	0.127	0.646	2.043	3.772	0.000
Skein et al., 2012	-0.547	0.314	0.099	-1.162	0.069	-1.742	0.082
Tyler et al., 2011	0.352	0.146	0.021	0.066	0.638	2.412	0.016
Ueckert et al., 2007	1.081	0.123	0.015	0.841	1.322	8.812	0.000
Overall weighted effect	0.485	0.080	0.006	0.328	0.641	6.067	0.000



Evidence Based Practice- Heat Adaptation

- *During* your event
  - Hydrate, hydrate, hydrate!
    - Sweat rate
    - Drink mix vs water
  - ***Cold drinks!***
    - Ice slurry
  - Ice and other auxiliary cooling methods



Evidence Based Practice- Heat Adaptation

During your event

- How much to drink?
  - More is more (2x normal feeds)
  - 1 cold bottle every 40-60 minutes
    - Still does not match sweat rate of up to 2.5L/ hr
  - Keep in mind gastro-intestinal considerations
- Performance when dehydrated
  - 2-4% loss of body mass to dehydration
  - 6-16% loss of Vo2 max

Evidence Based Practice- Heat Adaptation

24oz

20oz

33oz. 1 Liter

Evidence Based Practice- Heat Adaptation

During your event

- PER HOUR:

- 60oz.
- 2L

Evidence Based Practice- Heat Adaptation

During your event

- PER HOUR:

- 48oz.
- 1.4L

Evidence Based Practice- Heat Adaptation

During your event

- PER HOUR:

- 68oz.
- 2.01 L

Evidence Based Practice- Heat Adaptation

During your event

- PER HOUR:

- 66oz.
- 2.00 L

Evidence Based Practice- Heat Adaptation

VS

1.4 L / 48oz vs 2.0L/ 66oz per hr

Deficit:
5 hr= 3L. 101oz. 0.8 gal

8 hr= 4.8L. 162 oz. 1.25 gal

Evidence Based Practice- Heat Adaptation

Cramping?

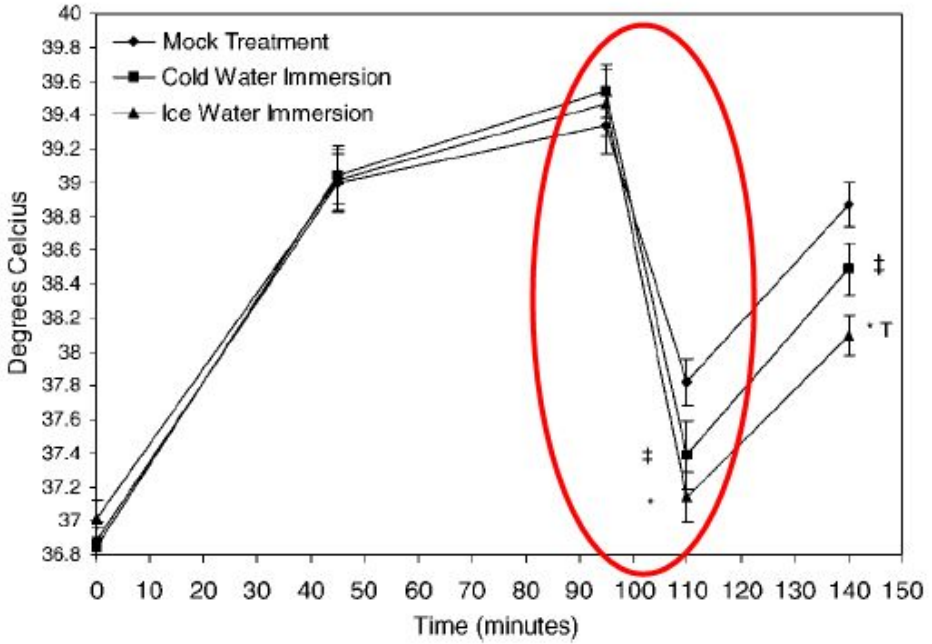
- Long established to have debunked the link between electrolytes and cramping
- Established that exercise-related muscle cramping originates in the motor neuron and is a result of nerve fatigue and muscle damage from lack of “fitness”

  - Spice- TRP channel agonists: HOT Shot
    - Combo Hydration and relative intensity cold have a role

Evidence Based Practice- Heat Adaptation

Post event

- Emphasis on bringing core temperature to normal ASAP
  - Ice slurry
  - *Cool water immersion*

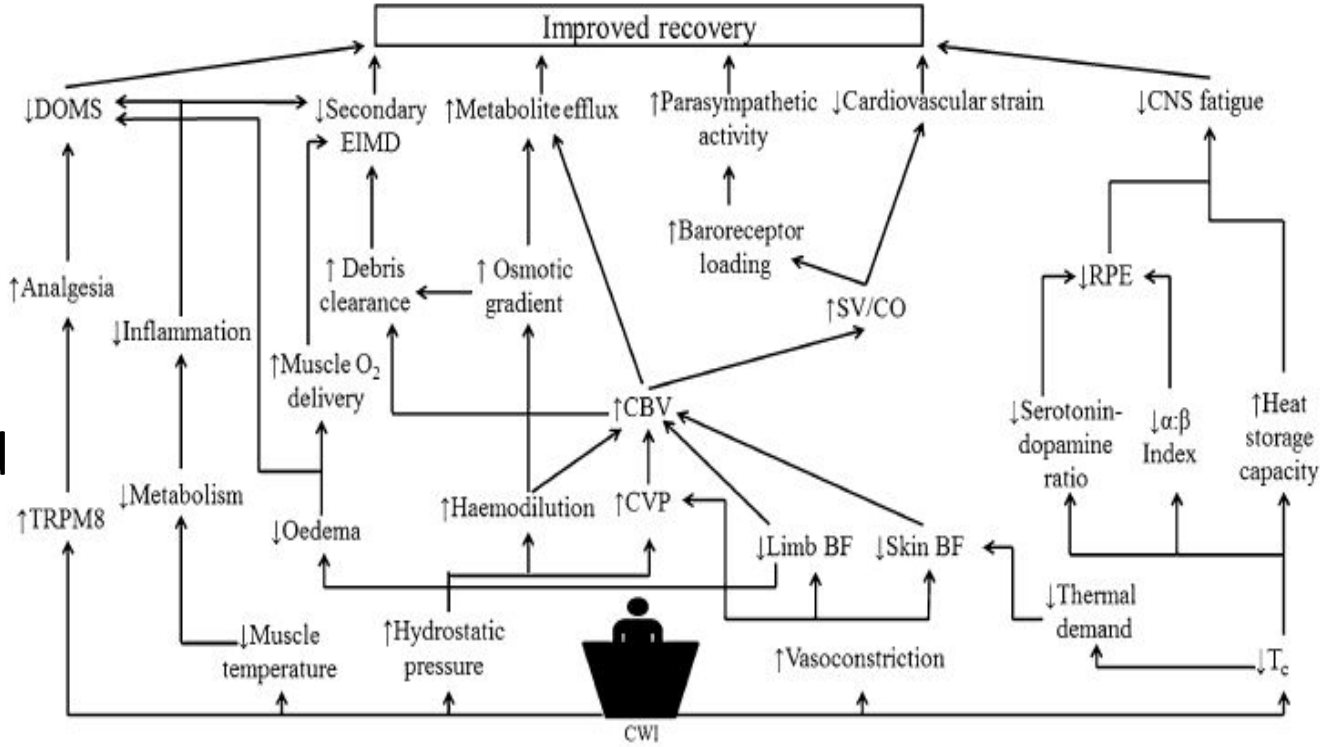


Yeargin et al. (2006)

Preserving Performance in hot conditions

Post event Cool Water Immersion

- Return to A/C
- Maintain elevated hydration



Ihsan et al. (2016)

Evidence Based Practice- Heat Adaptation

Adapting training to heat

- Competition still requires each of us to reach to that upper echelon of our physical ability
- Nationwide, ability is relatively consistent and thus, regardless of weather, there is still a demand for a high level of performance
    - Need for high power efforts has not diminished

Evidence Based Practice- Heat Adaptation

Adapting training to heat

- Train in the coolest conditions of the day- “Dawn Patrol”
  - Moderate heat (80F) can give you the same benefits but allow higher training stress
  - Consider indoor training if necessary to get the exposure at the highest intensities
- Maintain exposure to heat and the beneficial adaptations
- NEVER, ever stop with hydration. EVER.

Evidence Based Practice- Heat Adaptation

Hopefully you learned

- How does it affect performance?
- Physiological adaptations
- Behavior modification
- Improve performance in hot conditions

References

Braulick, Kyle W., et al. "Significant and serious dehydration does not affect skeletal muscle cramp threshold frequency." *British Journal of Sports Medicine* 47.11 (2013): 710-714.

Best, Russ, et al. "Topical and Ingested Cooling Methodologies for Endurance Exercise Performance in the Heat." *Sports* 6.1 (2018): 11.

Cheuvront, Samuel N., et al. "Mechanisms of aerobic performance impairment with heat stress and dehydration." *Journal of Applied Physiology*109.6 (2010): 1989-1995.

Daanen, Hein AM, Sebastien Racinais, and Julien D. Périard. "Heat acclimation decay and re-induction: a systematic review and meta-analysis." *Sports Medicine* 48.2 (2018): 409-430.

Duffield, Rob, and Frank E. Marino. "Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions." *European Journal of Applied Physiology* 100.6 (2007): 727-735.

Faulkner, Steve H., et al. "Conductive and evaporative precooling lowers mean skin temperature and improves time trial performance in the heat.“ *Scandinavian Journal of Medicine & Science in Sports* 25.S1 (2015): 183-189.

Faulkner, Steve H., et al. "The Threshold Ambient Temperature for the Use of Precooling to Improve Cycling Time-Trial Performance." *International journal of sports physiology and performance* 14.3 (2019): 323-330.

Fox, R. H., et al. "The nature of the increase in sweating capacity produced by heat acclimatization." *The Journal of Physiology* 171.3 (1964): 368.

Fritzsche, Ricardo G., et al. "Water and carbohydrate ingestion during prolonged exercise increase maximal neuromuscular power." *Journal of Applied Physiology* 88.2 (2000): 730-737.

Galloway, S. D., and Ronald J. Maughan. "Effects of ambient temperature on the capacity to perform prolonged cycle exercise in man." *Medicine and science in sports and exercise*29.9 (1997): 1240-1249.

Hatzigeorgiadis, Antonis, et al. "Beat the Heat: Effects of a Motivational Self-Talk Intervention on Endurance Performance." *Journal of Applied Sport Psychology* 30.4 (2018): 388-401.

Heathcote, Storme Louise, et al. "Passive heating: reviewing practical heat acclimation strategies for endurance athletes." *Frontiers in physiology* 9 (2018): 1851.

Hohenauer, Erich, et al. "The effect of pre-exercise cooling on performance characteristics: A systematic review and meta-analysis." *Int. J. Clin. Med* 9 (2018): 117-141.

Hoffman, Martin D., and Kristin J. Stuempfle. "Muscle cramping during a 161-km ultramarathon: comparison of characteristics of those with and without cramping." *Sports Medicine-Open* 2.1 (2015): 8.

References, cont.

Ihsan, Mohammed, Greig Watson, and Chris R. Abbiss. "What are the Physiological Mechanisms for Post-Exercise Cold Water Immersion in the Recovery from Prolonged Endurance and Intermittent Exercise?." *Sports Medicine* (2016): 1-15.

Ingham-Broomfield, R. (2016). A nurses' guide to the hierarchy of research designs and evidence. *The Australian Journal of Advanced Nursing,* 33 (3) pp 38-43.

Jung, Alan P., et al. "Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps." *Journal of Athletic Training* 40.2 (2005): 71.

Karlsen, Anders, et al. "Time course of natural heat acclimatization in well-trained cyclists during a 2-week training camp in the heat." *Scandinavian Journal of Medicine & Science in Sports* 25.S1 (2015): 240-249.

Lorenzo, Santiago, et al. "Heat acclimation improves exercise performance." *Journal of Applied Physiology* 109.4 (2010): 1140-1147.

Mejuto, Gaizka, et al. "The effect of ice ingestion during endurance exercise." *Extreme Physiology & Medicine* 4.1 (2015): 1.

Miller, Kevin C. "Myths and Misconceptions About Exercise-Associated Muscle Cramping." *ACSM's Health & Fitness Journal* 20.2 (2016): 37-39.

Minetto, Marco Alessandro, et al. "Origin and development of muscle cramps." *Exercise and Sport Sciences Reviews* 41.1 (2013): 3-10.

Nielsen, Bodil, et al. "Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment." *The Journal of Physiology* 460 (1993): 467.

Nybo, Lars. "Brain temperature and exercise performance." *Experimental Physiology* 97.3 (2012): 333-339.

Périard, J. D., and S. Racinais. "Training and competing in the heat." *Scandinavian Journal of Medicine & Science in Sports* 25.S1 (2015): 2-3.

References, cont.

Racinais, Sebastien, et al. "Effect of heat and heat acclimatization on cycling time trial performance and pacing." *Medicine and Science in Sports and Exercise* 47.3 (2015): 601.

Rahimi, Gholam R. Mohammed, et al. "Physiological Responses to Heat Acclimation: A Systematic Review and Meta-Analysis of Randomized Controlled Trials." *Journal of Sports Science & Medicine* 18.2 (2019): 316.

Sawka, Michael N., Julien D. Périard, and Sébastien Racinais. "Heat acclimatization to improve athletic performance in warm-hot environments." *Sports Science* 28.153 (2015): 1-6.

Stevens, Christopher J., et al. "Effect of two-weeks endurance training wearing additional clothing in a temperate outdoor environment on performance and physiology in the heat." *Temperature* 5.3 (2018): 267-275.

Schulze, Emiel, et al. "Effect of thermal state and thermal comfort on cycling performance in the heat." *International Journal of Sports Physiology and Performance* 10 (2015): 655-663.

Sulzer, Nicole U., Martin P. Schwellnus, and Timothy D. Noakes. "Serum electrolytes in Ironman triathletes with exercise-associated muscle cramping." *Medicine and Science in Sports and Exercise* 37.7 (2005): 1081-1085.

Tatterson, Abbey J., et al. "Effects of heat stress on physiological responses and exercise performance in elite cyclists." *Journal of Science and Medicine in Sport* 3.2 (2000): 186-193.

Tyler, Christopher J., et al. "The effects of heat adaptation on physiology, perception and exercise performance in the heat: a meta-analysis." *Sports Medicine* 46.11 (2016): 1699-1724.

Willmott, A. G. B., et al. "The effects of single versus twice daily short term heat acclimation on heat strain and 3000m running performance in hot, humid conditions." *Journal of Thermal Biology* (2016).

Yeargin, Susan W., et al. "Body cooling between two bouts of exercise in the heat enhances subsequent performance." *The Journal of Strength & Conditioning Research* 20.2 (2006): 383-389.

References, cont.

Zimmermann, Matthew, et al. "Precooling wth crushed ice: as effective as heat acclimation at improving cycling time-trial performance in the heat." *International journal of sports physiology and performance* 13.2 (2018): 228-234.

Zhang, Yang. "Optimizing ice slurry ingestion for endurance performance in the heat: a meta-analysis." *Journal of Anthropology of Sport and Physical Education* 3.1 (2019): 3-8.

Zurawlew, Michael J., Jessica A. Mee, and Neil P. Walsh. "Heat Acclimation by Postexercise Hot-Water Immersion: Reduction of Thermal Strain During Morning and Afternoon Exercise-Heat Stress After Morning Hot-Water Immersion." *International journal of sports physiology and performance*13.10 (2018): 1281-1286.

Zurawlew, Michael J., Jessica A. Mee, and Neil P. Walsh. "Post-exercise hot water immersion elicits heat acclimation adaptations in endurance trained and recreationally active individuals." *Frontiers in physiology* 9 (2018).

Questions?

- For more articles and athlete highlights from Source Endurance: http://source-e.net
- To schedule a follow up 10 minute consult with a SE coach or sign up for coaching stick around and we'll redirect you to a page where you can request a consult.