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Training and competition in the heat and in the cold

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November 9, 2023

The Olympic Games in Tokyo (2021)

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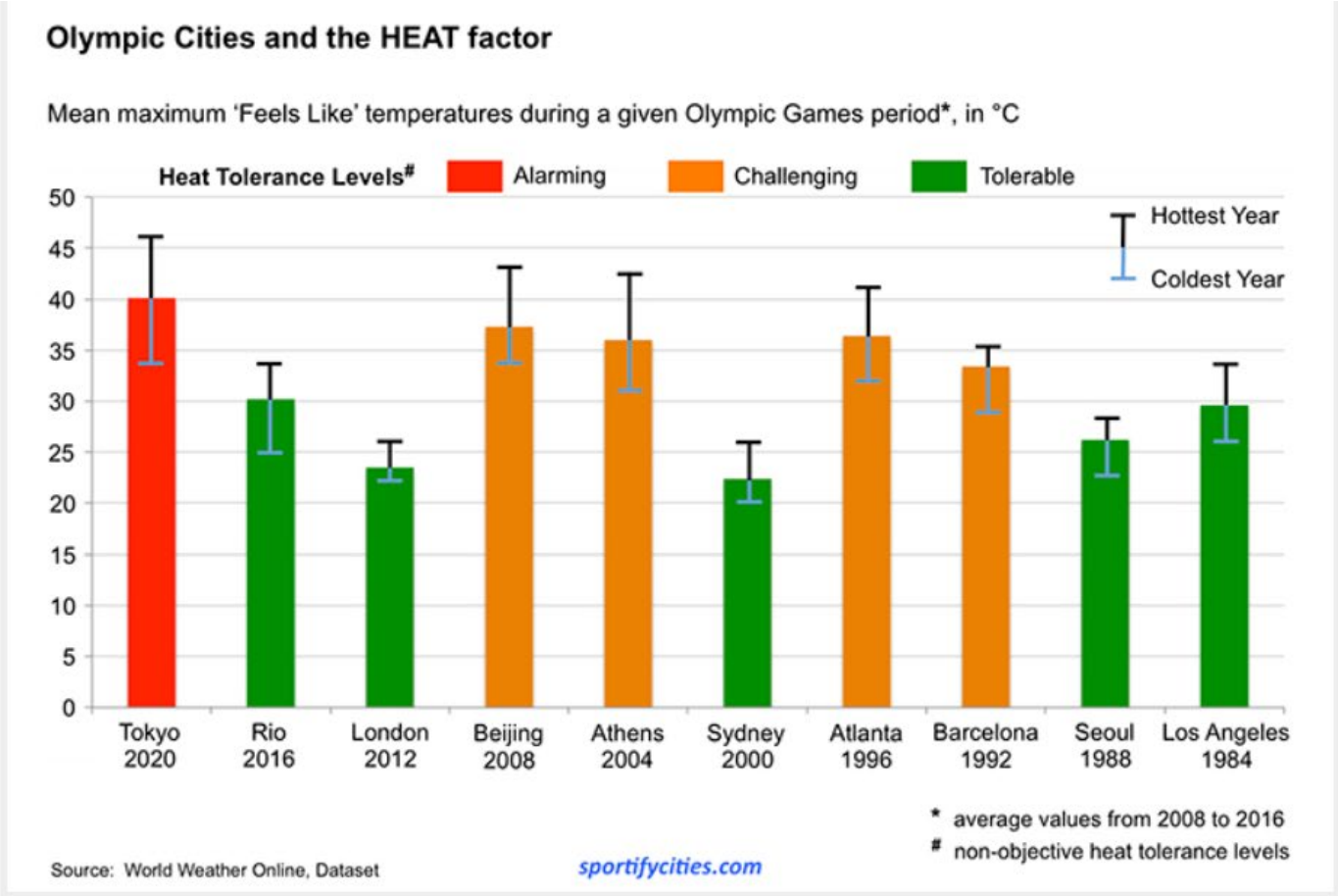

TOKYO 2020

Athletes competing at the 2020 Tokyo Olympics are likely to be exposed to the hottest perceived temperatures ever experienced during the modern Summer Olympic Games.

Hot also during paralympics

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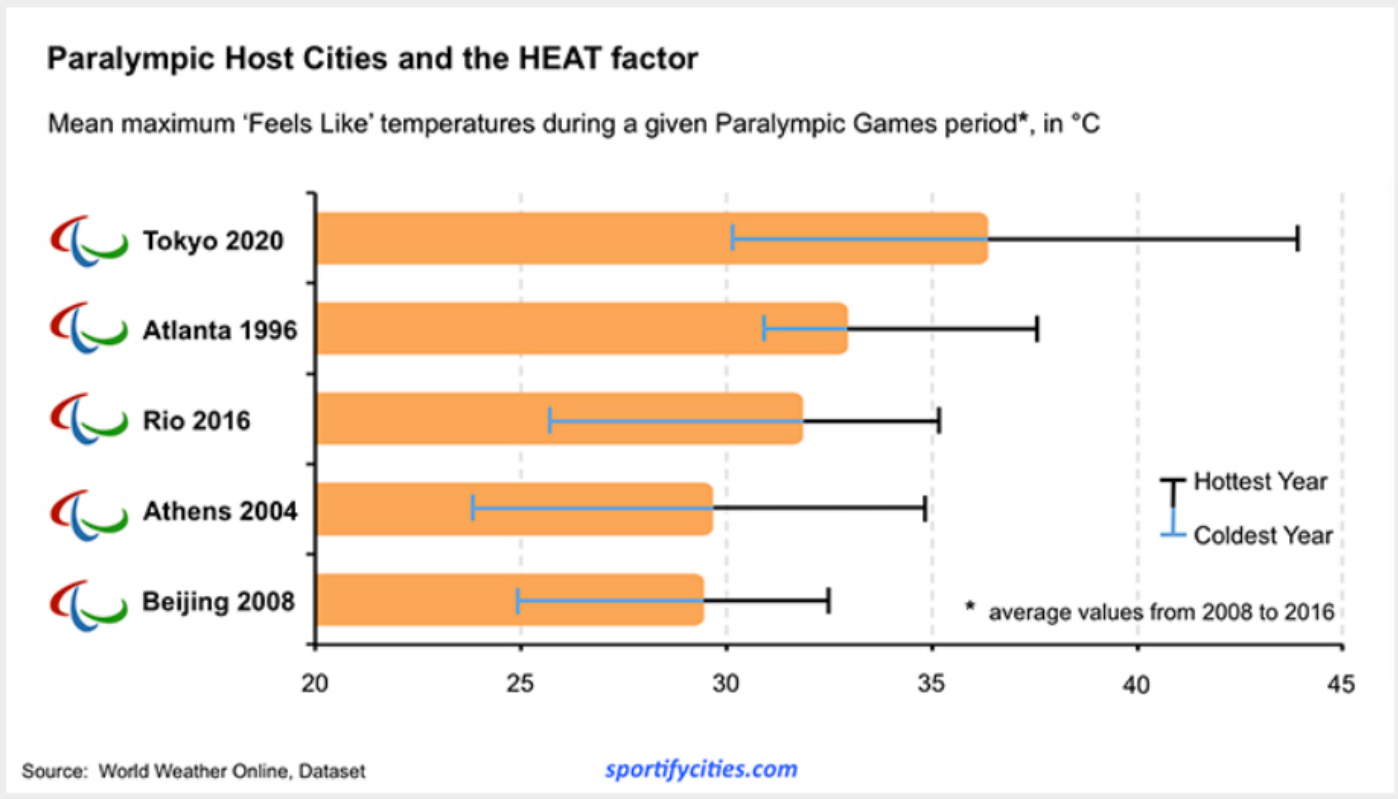
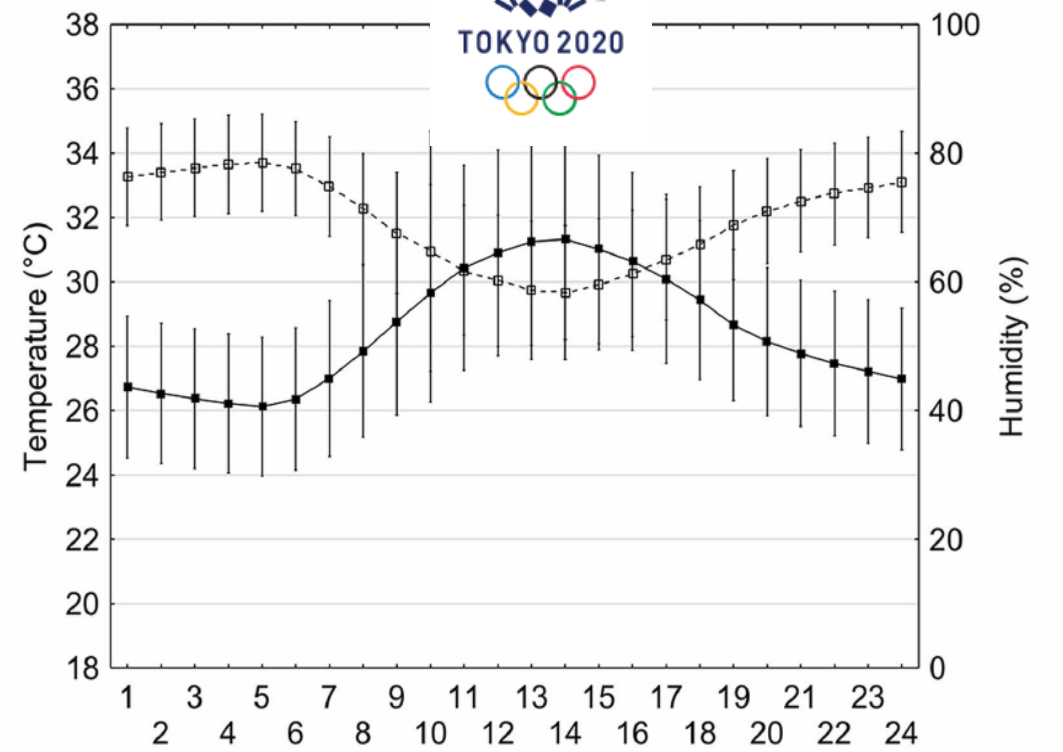


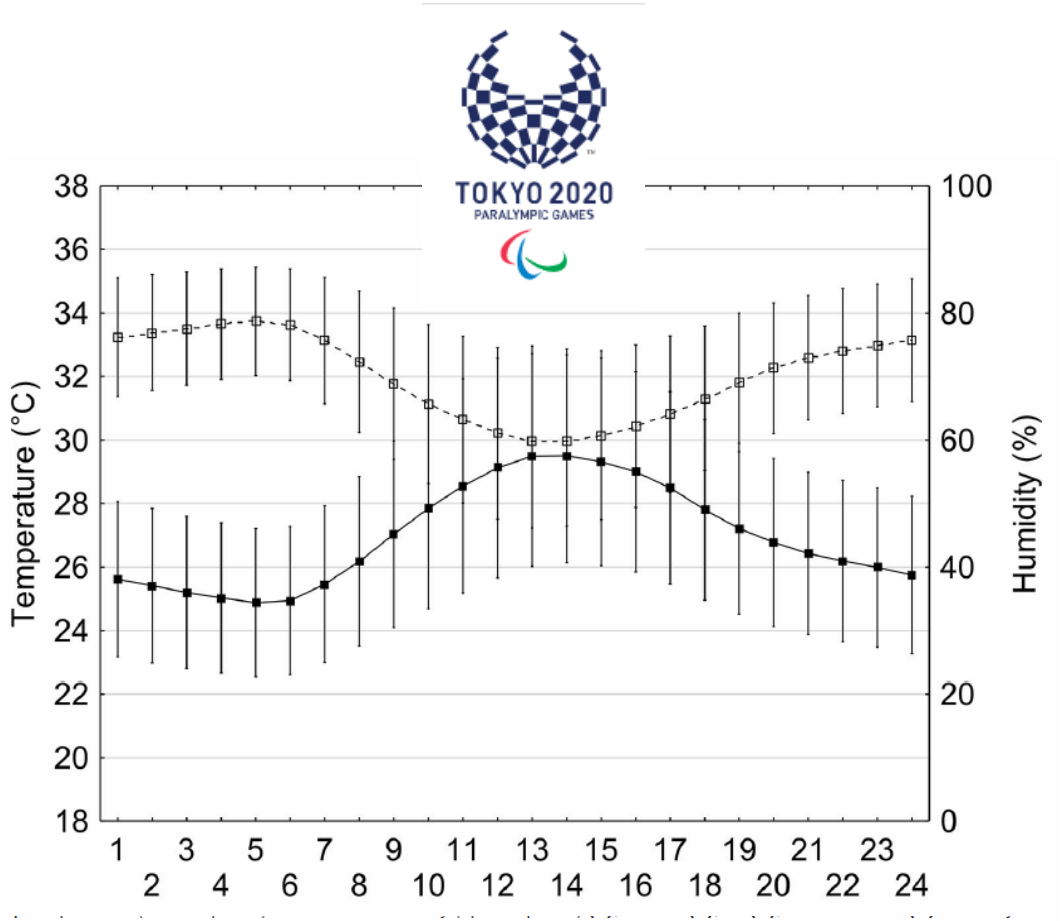
TOKYO 2020
PARALYMPIC GAMES

The graph ranks the five warmest host cities of the Summer Paralympic Games (based on temperatures recorded during a given Paralympics period). With an average maximum *feels like* temperature of 36°C Tokyo clearly tops this heat ranking.

Hourly ambient temperature and relative humidity (last 29 years)



the past 29 years (1990–2018) during the dates corresponding to the Olympic period (July 24th until August 9th)



the past 29 years (1990–2018) during the dates corresponding to the Paralympic period (August 25th until September 6th).

Gerret et al 2019

How hot does it feel?

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Table 3
Effects of the heat index (shade values).

Fahrenheit	Celsius	Notes
80–90 °F	27–32 °C	Caution — fatigue is possible with prolonged exposure and activity
90–105 °F	32–41 °C	Extreme caution — sunstroke, heat cramps, and heat exhaustion are possible
105–130 °F	41–54 °C	Danger — sunstroke, heat cramps, and heat exhaustion are likely; heat stroke is possible
over 130 °F	over 54 °C	Extreme danger — heat stroke or sunstroke are likely with continued exposure

NWS (National Weather Services 2014

	Temperature (˚C)												
RH (%)	26	27	28	29	30	31	32	33	34	35	36	37	38
90	28	31	34	37	41	44	49	54	59	64	69	75	81
85	28	30	33	36	39	43	47	51	55	60	65	70	76
80	28	30	32	35	38	41	44	48	52	57	61	66	71
75	28	29	31	34	36	39	42	46	49	53	58	62	67
70	27	29	31	33	35	38	40	44	47	50	54	58	63
65	27	29	30	32	34	36	39	41	44	48	51	55	59
60	27	28	30	31	33	35	37	40	42	46	48	51	55
55	27	28	29	30	32	34	36	38	40	44	46	48	52
50	27	27	29	30	31	33	34	36	38	41	43	46	49
45	26	27	28	29	30	32	33	35	37	39	41	43	46
40	26	27	28	29	30	31	32	34	35	37	39	41	43
35	26	27	27	28	29	30	32	33	34	36	38	39	41
30	26	26	27	28	29	30	31	32	33	35	36	38	39

Heat index in Tokyo in last 29 years

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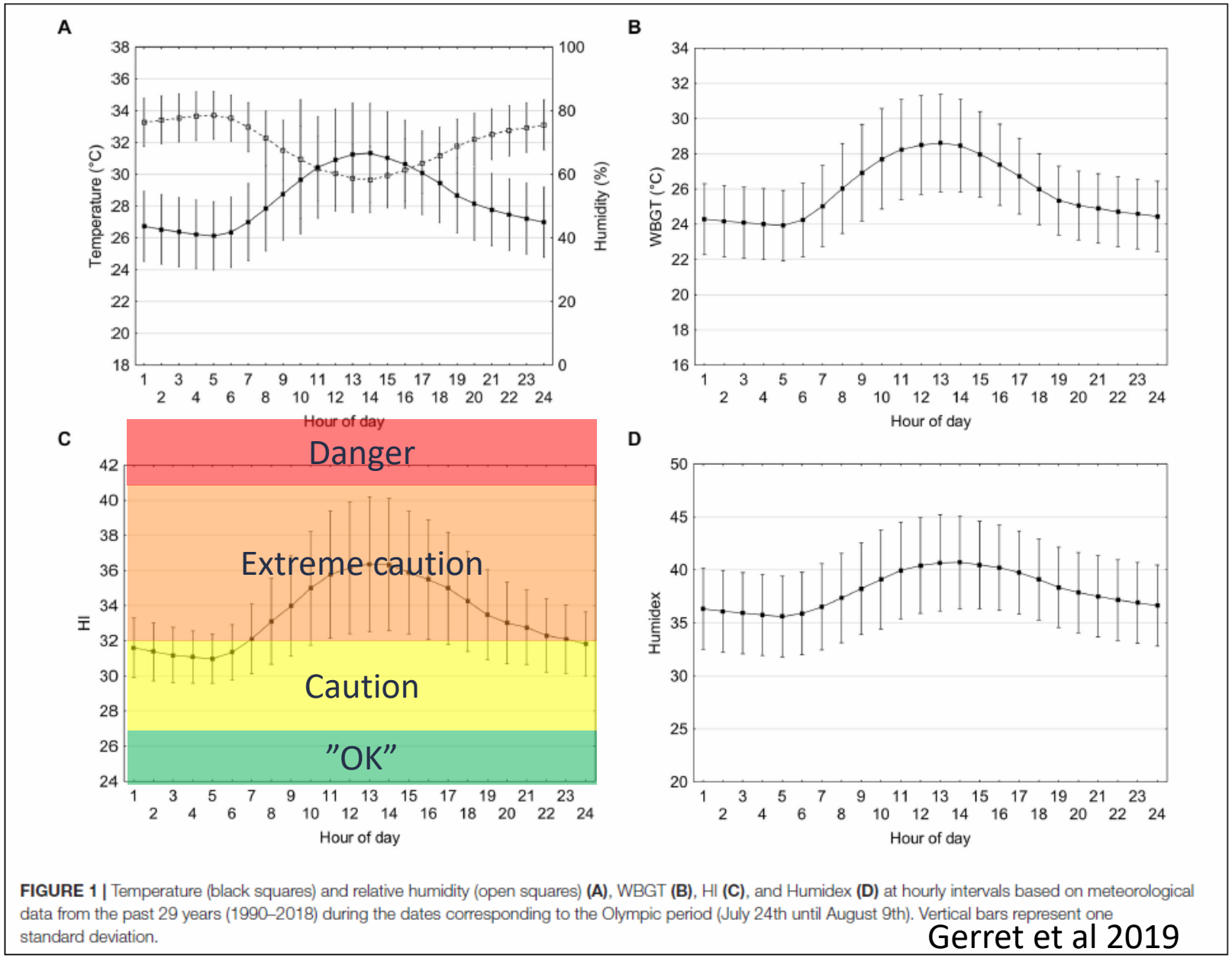

FIGURE 1 | Temperature (black squares) and relative humidity (open squares) **(A)**, WBGT **(B)**, HI **(C)**, and Humidex **(D)** at hourly intervals based on meteorological data from the past 29 years (1990–2018) during the dates corresponding to the Olympic period (July 24th until August 9th). Vertical bars represent one standard deviation.

Gerret et al 2019

Heat index in Tokyo in last 29 years

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PARALYMPIC GAMES

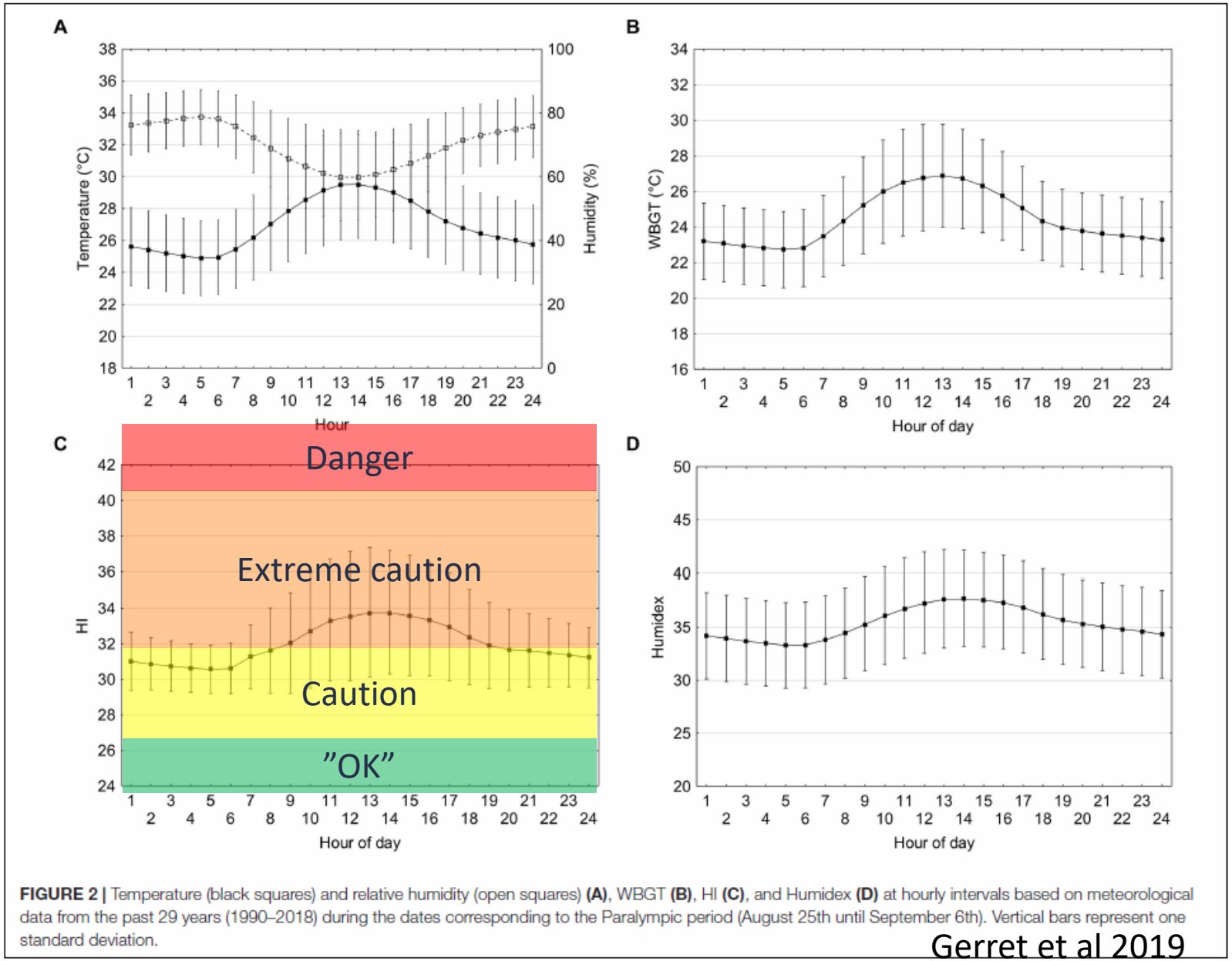

FIGURE 2 | Temperature (black squares) and relative humidity (open squares) **(A)**, WBGT **(B)**, HI **(C)**, and Humidex **(D)** at hourly intervals based on meteorological data from the past 29 years (1990–2018) during the dates corresponding to the Paralympic period (August 25th until September 6th). Vertical bars represent one standard deviation.

Gerret et al 2019

Let's add the solar radiation!

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TABLE 1 | Minimum, first quartile, median, third quartile, and maximum solar radiation at hourly intervals based on meteorological data from the past 29 years (1990–2018) during the dates corresponding to the Olympic period (July 24th until August 9th) and Paralympic period (August 25th until September 6th).

	Solar radiation (W/m^2) Olympic period					Solar radiation (W/m^2) Paralympic period				
	Minimum	First quartile	Median	Third quartile	Maximum	Minimum	First quartile	Median	Third quartile	Maximum
05:00	0	0	0	3	14	0	0	3	6	22
06:00	0	19	42	69	122	0	9	39	72	158
07:00	0	58	131	206	328	0	26	106	192	411
08:00	0	111	233	392	553	3	49	194	358	569
09:00	8	153	353	539	711	3	68	286	506	733
10:00	0	194	483	678	853	3	85	331	619	869
11:00	0	236	561	783	942	4	95	408	703	961
12:00	0	286	636	839	953	2	115	450	728	1000
13:00	0	281	608	825	942	3	109	456	747	981
14:00	0	242	550	764	900	3	99	419	689	914
15:00	0	225	469	650	797	3	82	367	592	817
16:00	0	153	331	489	614	2	60	253	419	631
17:00	0	97	189	306	422	0	34	150	264	444
18:00	0	42	86	139	225	0	15	69	122	217
19:00	0	8	17	25	67	0	3	14	25	47
20:00	0	0	0	0	3	0	0	0	0	3
21:00–04:00	0	0	0	0	0	0	0	0	0	0

Gerret et al 2019

And what really happened?

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Olympic athletes and volunteers in Tokyo 'tortured' by hottest Games ever

Hottest Olympics in history will put pressure on organisers to rethink sport in light of climate crisis

▲ Paula Badosa of Spain is helped off court in a wheelchair having suffered heat exhaustion. Photograph: Seth Wenig/AP

Olympic athletes and volunteers in Tokyo are being "tortured" by dangerous heat, meteorologists have said, as the hottest Games in history puts pressure on organisers to rethink the future of sport in a climate-disrupted world.

Temperatures hit 34C in the Japanese capital on Thursday with humidity of nearly 70%. Athletes and sports scientists say the combination of heat and moisture has led to "brutal" conditions that must be avoided at future events.

The Guardian, Aug 5th, 2021

"I can finish the match, but I can die," Medvedev replied. "If I die, are you going to be responsible?"

Afterward, Medvedev said he felt "darkness" in his eyes.

"I didn't know what to do to feel better," the Russian Olympic Committee player added. "I was ready to just fall down on the court."

Daniil Medvedev received medical treatment and had his chest massaged while up 5-2 in the first set. He then took another medical timeout while trailing 4-3 in the second. "I felt like my diaphragm has blocked," he said. "I couldn't breathe properly." RUNGROJ YONGRIT/EPA-EFE

Associated Press, July 28th, 2021

August 2022 Day +29°C Night +20°C

August 2021 Day +25°C Night +17°C

August 2020 Day +28°C Night +20°C

- Highest temperatures between 33-35 ˚C

https://world-weather.info/forecast/hungary/budapest/
accessed April 21, 2023

August 2023	Day +23°C	Night +18°C
August 2022	Day +27°C	Night +20°C
August 2021	Day +22°C	Night +17°C
August 2020	Day +26°C	Night +20°C

- Highest temperatures between 29-37 ˚C

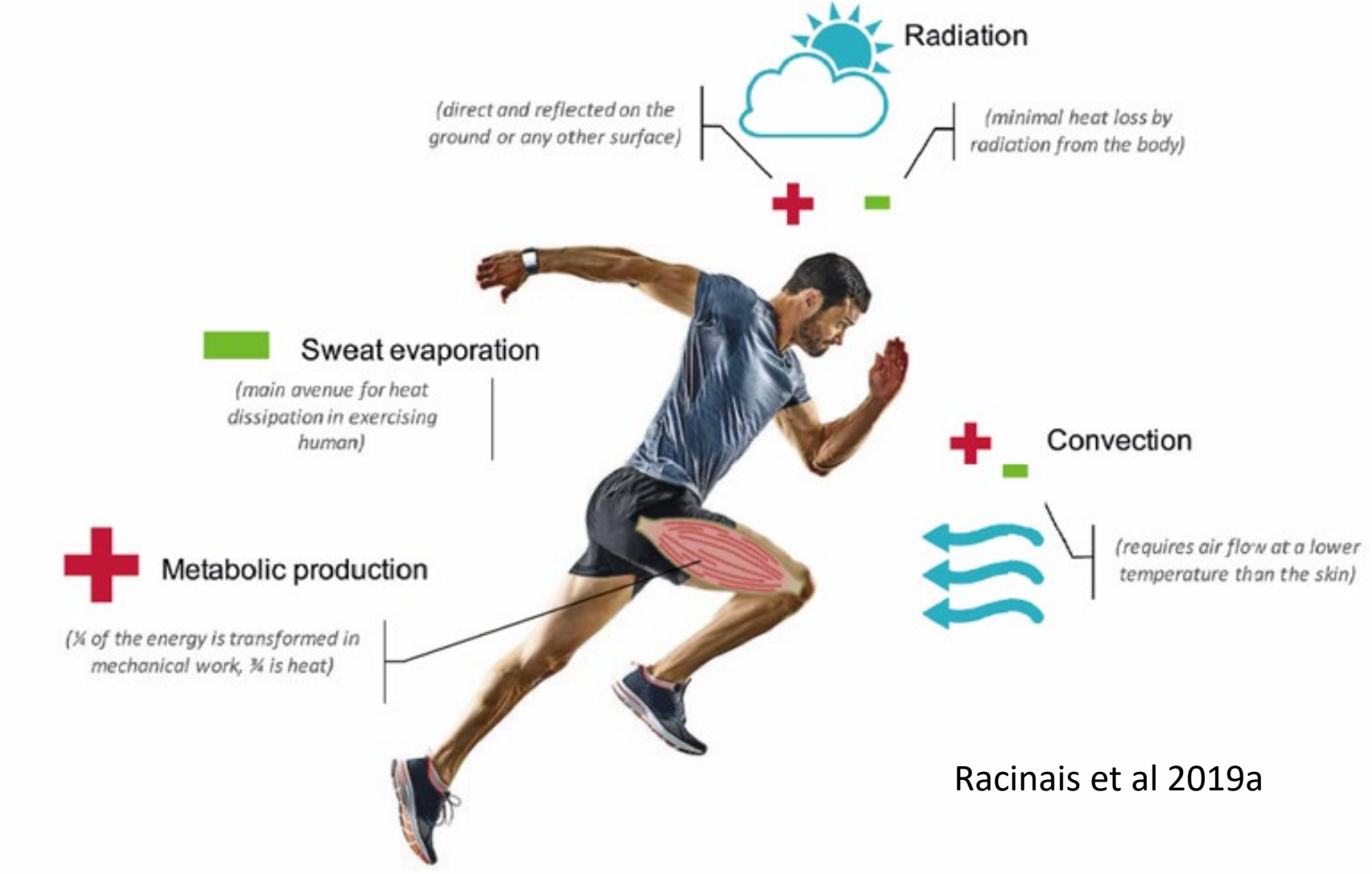
Weather in Paris in August 2024

Paris Weather Forecast for August 2024, is based on previous years statistical data.

1	2	3	4	5	6	7	8	9	10	11
+25° night +21°	+26° night +21°	+26° night +21°	+26° night +21°	+26° night +21°	+26° night +21°	+27° night +20°	+26° night +21°	+25° night +20°	+26° night +20°	+27° night +22°

https://world-weather.info/forecast/france/paris/
accessed October 5th, 2023

The athlete's thermal environment – exercising in the heat



Racinais et al 2019a

Cognitive challenges in the heat

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- ”Global Workspace Theory”
- Changes in skin and in core temperature are effective

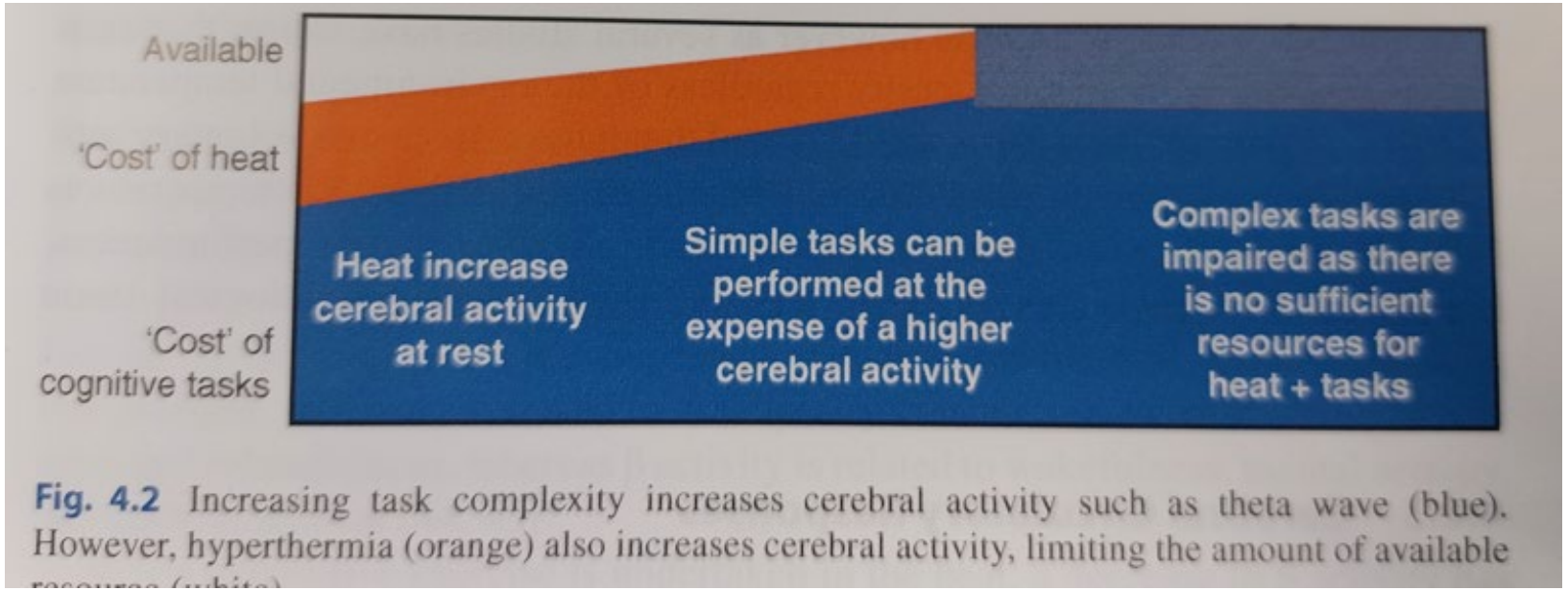

Fig. 4.2 Increasing task complexity increases cerebral activity such as theta wave (blue). However, hyperthermia (orange) also increases cerebral activity, limiting the amount of available

Racinais ym 2019

Effects of heat on running performance

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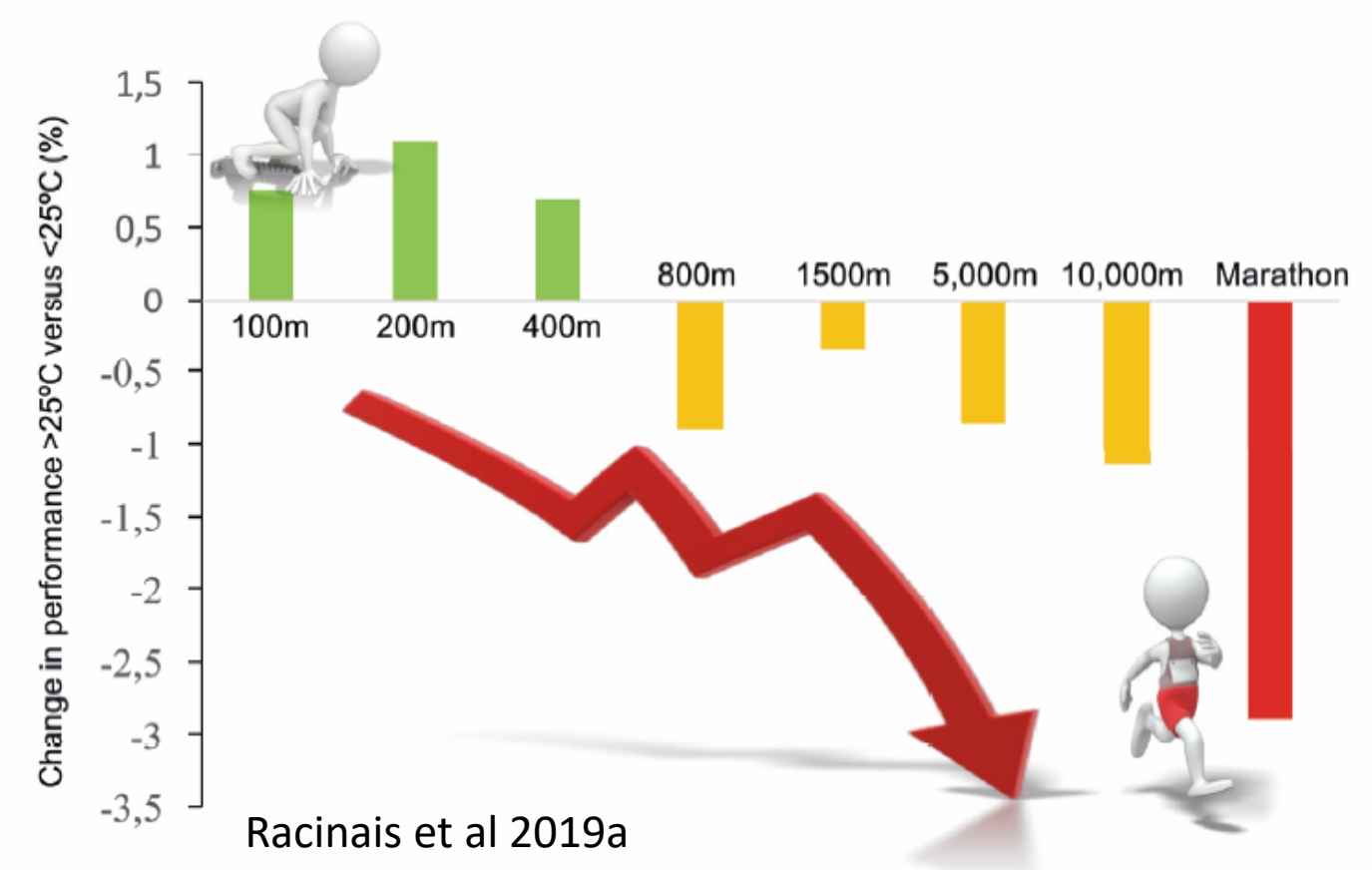
- Heat is beneficial for explosive athletic performance
  - Sprints, jumps, throws
- In longer events, rise in core temperature is a challenge, impairing performance



Racinais et al 2019a

Endurance exercise in different ambient temperatures

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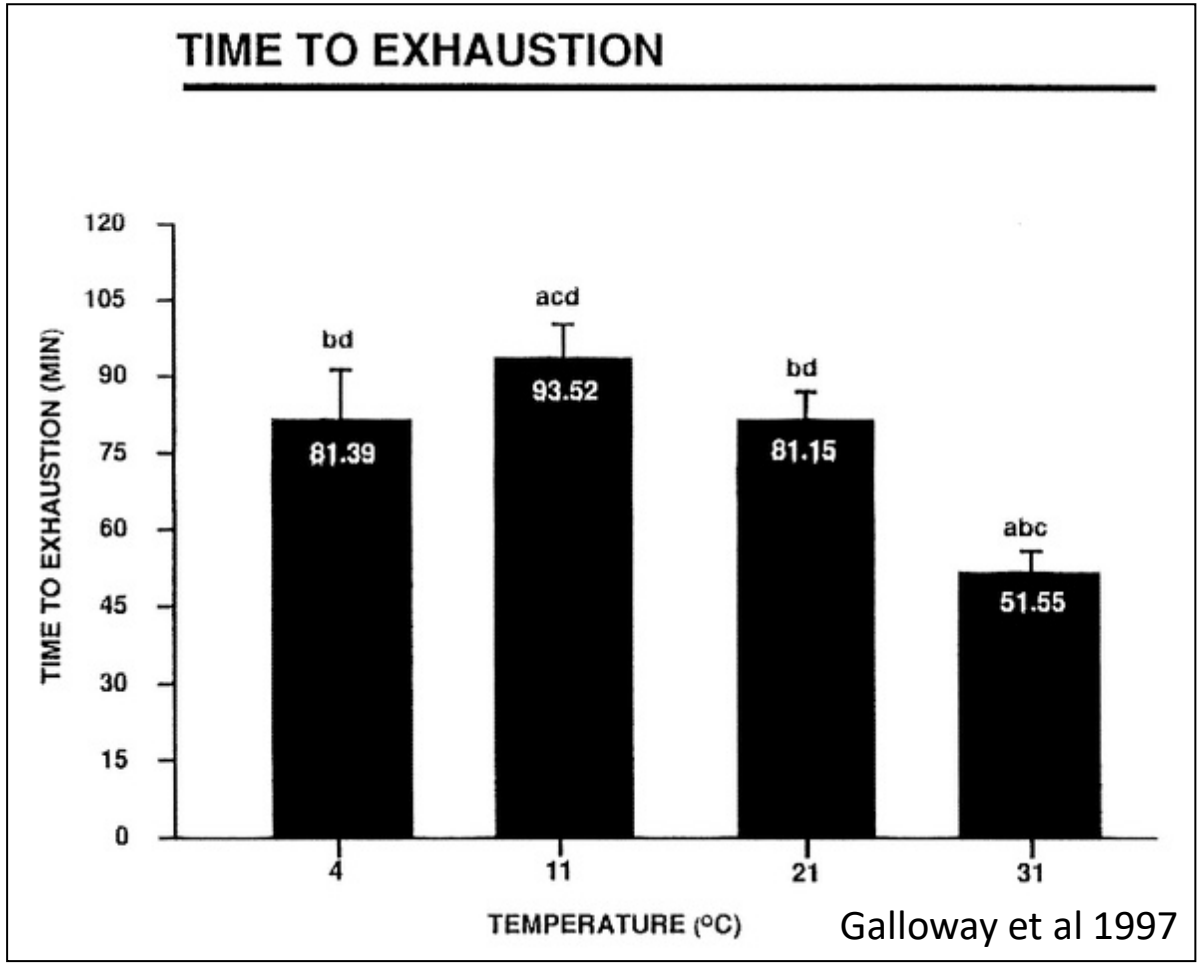
- 8 males on cycle ergometer
- TTE @ 70 % of VO_{2max}
- Relative humidity 70 %
- Air velocity 0.7 m/s
- At 4, 11, 21 and 31°C
- No drinking allowed



Galloway et al 1997

Endurance exercise in different ambient temperatures

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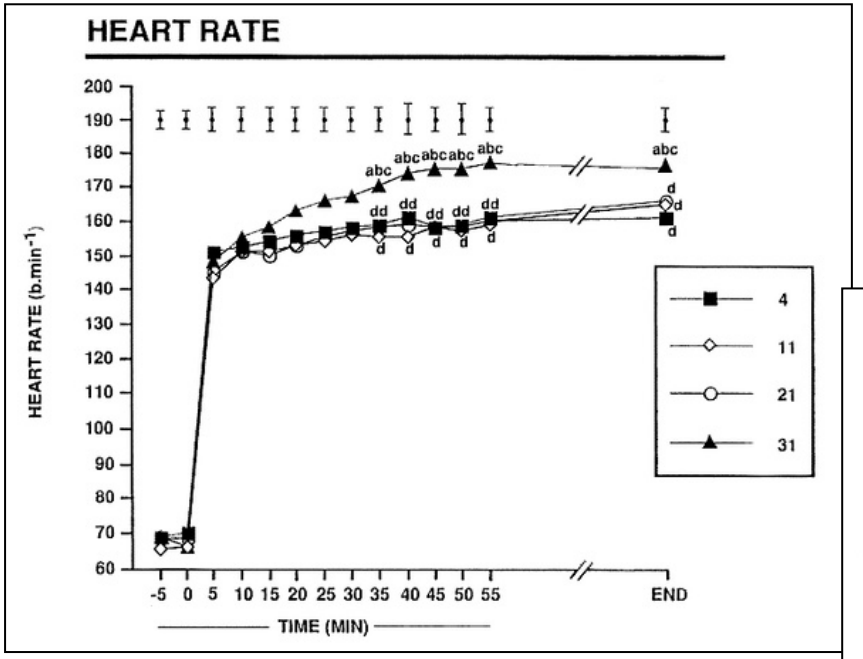

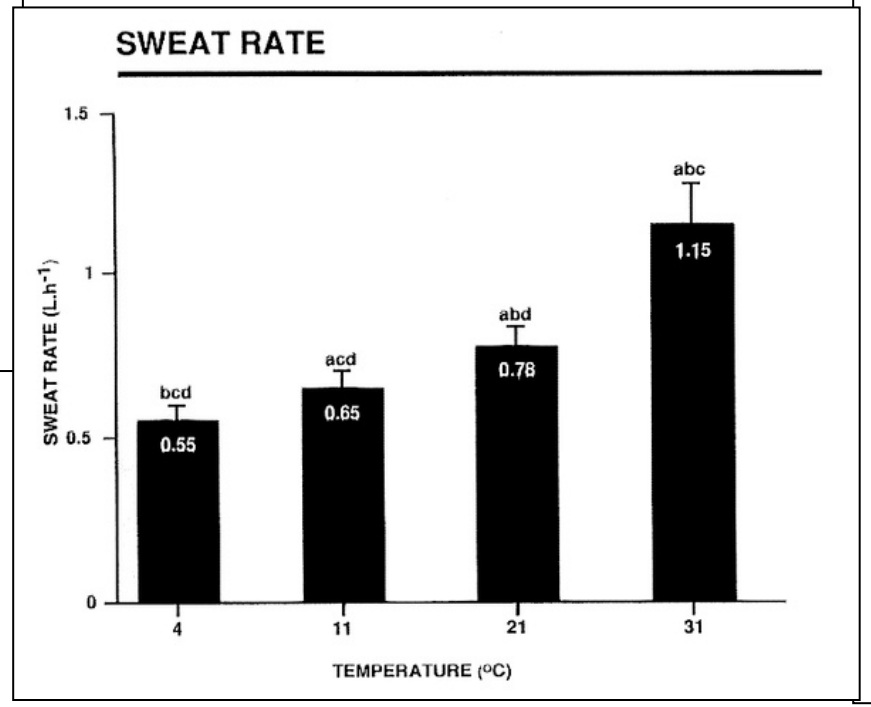

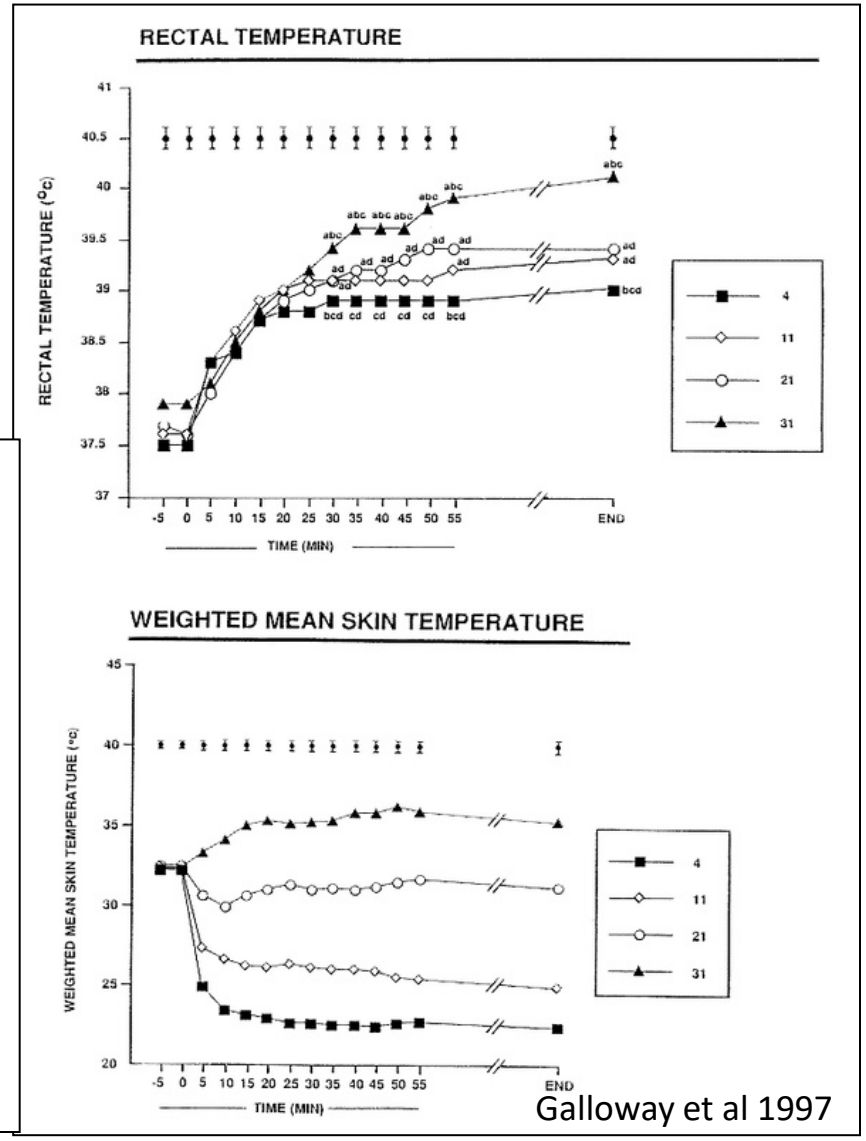

Galloway et al 1997

Effects of heat on long endurance performance

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IAAF World Athletics Championships
DOHA2019

by S. Racinais
@ephysiol

Event: 50k RW, Men
Date: 28th September 2019
Start time: 23h30
Location: Corniche

Temperature: 31.1ºC
Relative humidity: 75.5%
Wind speed: 0.4 $m.s^{-1}$
Radiation: Night
WBGT: 28.2ºC

	Temperature (°C)												
RH (%)	26	27	28	29	30	31	32	33	34	35	36	37	38
90	28	31	34	37	41	44	49	54	59	64	69	75	81
85	28	30	33	36	39	43	47	51	55	60	65	70	76
80	28	30	32	35	38	41	44	48	52	57	61	66	71
75	28	29	31	34	36	39	42	46	49	53	58	62	67
70	27	29	31	33	35	38	40	44	47	50	54	58	63
65	27	29	30	32	34	36	39	41	44	48	51	55	59
60	27	28	30	31	33	35	37	40	42	46	48	51	55
55	27	28	29	30	32	34	36	38	40	44	46	48	52
50	27	27	29	30	31	33	34	36	38	41	43	46	49
45	26	27	28	29	30	32	33	35	37	39	41	43	46
40	26	27	28	29	30	31	32	34	35	37	39	41	43
35	26	27	27	28	29	30	32	33	34	36	38	39	41
30	26	26	27	28	29	30	31	32	33	35	36	38	39

Starter: 46
Finisher: 28 (61%)
DNF: 14 (30%)
DQ: 4 (9%)

Winner: Yusuke Suzuki
Winner time: 4h 04min 20s
Winner relative time: 112% of his PB

Average relative time
of the finishers: 115% of PB
Best relative: 107% of PB
Worst relative: 128% of PB

Same relative difference as winning 100 m in 11.00 s (with PB of 9.83 s)

Competing in endurance event in the heat

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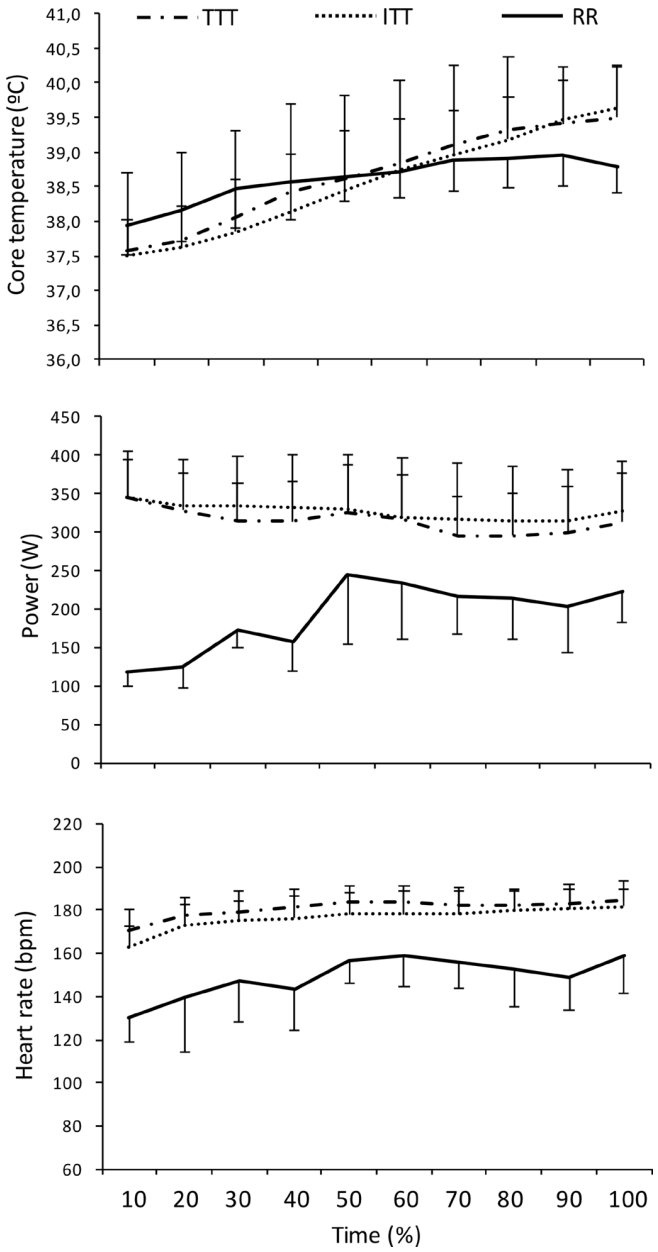
- 2016 Union Cycliste Internationale (UCI) Road World Championships (Doha, Qatar, 9 October–16 October)
- Direct sunlight 37°C ± 3°C, but dry (relative humidity 25 % ± 16 %)
- TTT was 40 km for both, ITT was 28.9 km for women and 40 km for men, and RR was 134.5 km for women and 257.5 km for men

Racinais et al. 2019b

Cycling race in the heat



- Core temperature rising through the race
- Power output decreased during the time trials until the end spurt to finish
- There was no relationship between core temperature and ranking (R^2=0.09) or exercise duration (R^2=0.14)
- None of the athletes were treated for heat illness

Racinais et al. 2019b

10/40 cyclists exceeded 40˚C

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- Higher core temperatures in time trials than in road race
- Athletes may have high core temperatures without ill-effects
- In a given thermal environment, exercise intensity is more important than duration

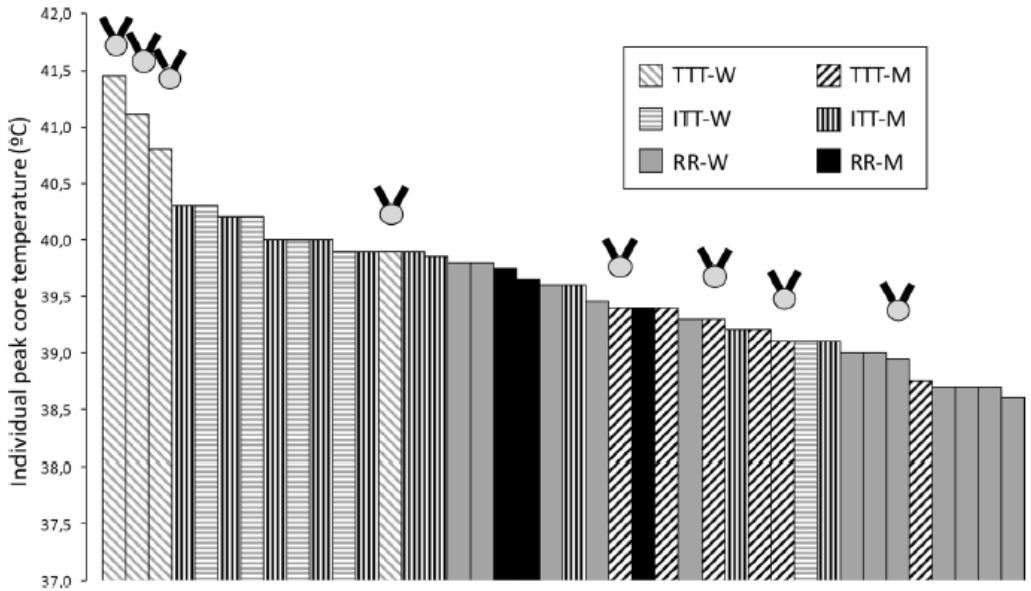

Figure 1 Peak core temperature reached during the team time trial (TTT), individual time trial (ITT) and road race (RR) of the 2016 UCI Road World Championship. Each column represents an individual value from an elite male (M) or female (F) cyclist. The medals symbolise data points of medallists in the corresponding event. W, watts.

Racinais et al 2019b

Keeping cool during training and competitions

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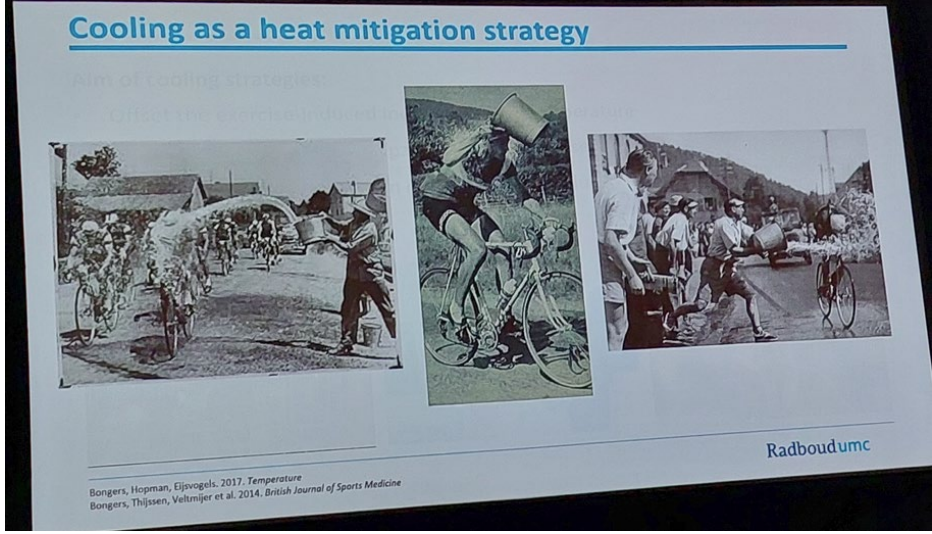
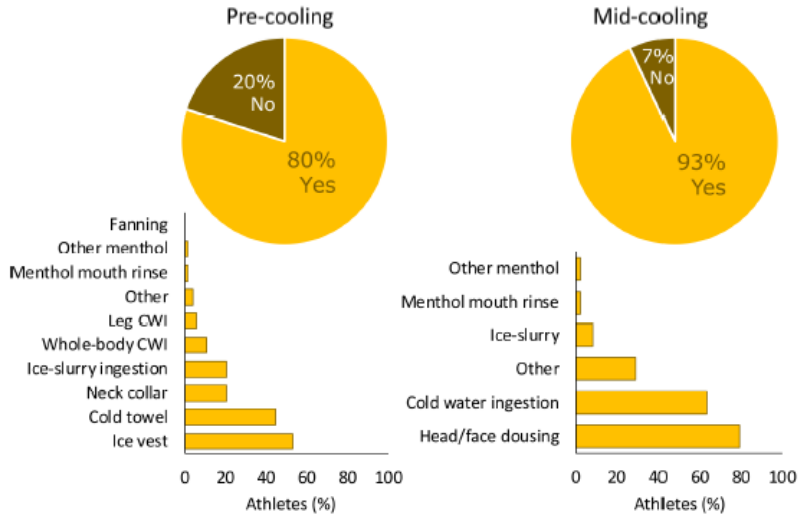
- Not an overwhelming problem during low-intensity training
  - However, speed/power at given heart rate is lower
- More challenging during high-intensity training and competitions
  - How to keep cool?

Cooling



- Most popular method has been cold water immersion, followed by ice vests, cold drinks, … *(Bongers et al 2020)*
- Pre-cooling the core is safe and practical method
  - Easy, no gastrointestinal symptoms
- In long endurance events (marathon, race walking) also working muscles may be cooled
  - Important to practice / test in advance!
- Thermal comfort (for everybody)
- Awareness has improved during last couple of years
  - Women less aware than men?



Racinais ym 2021

Cooling strategies

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- Pre-cooling
  - Before start to create a larger heat storage capacity
  - Cooling/ice-vests, cold water ingestion, ice slurry ingestion, cold water immersion, etc.
- Per-cooling
  - During the exercise
  - Same methods as above, but not (all) as practical
- Post-cooling
  - Cold water immersion, cryotherapy

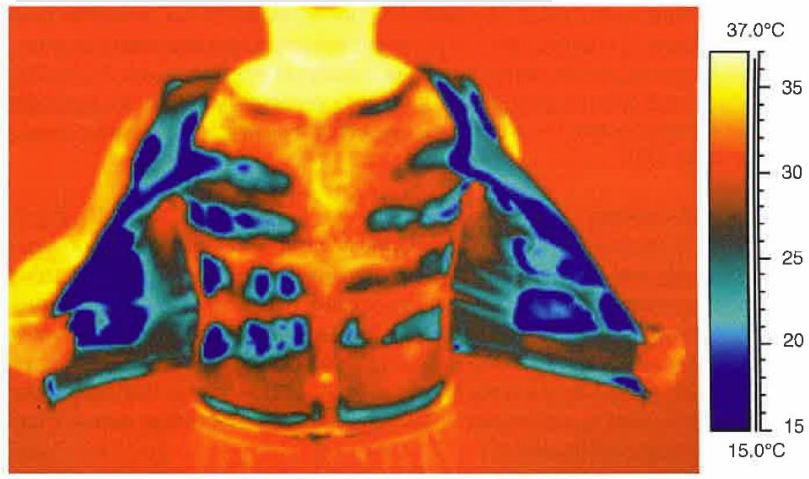

Fig. 7.2 Thermal image showing the localised cooling offered by an ice vest

Are cooling strategies beneficial? KIHU

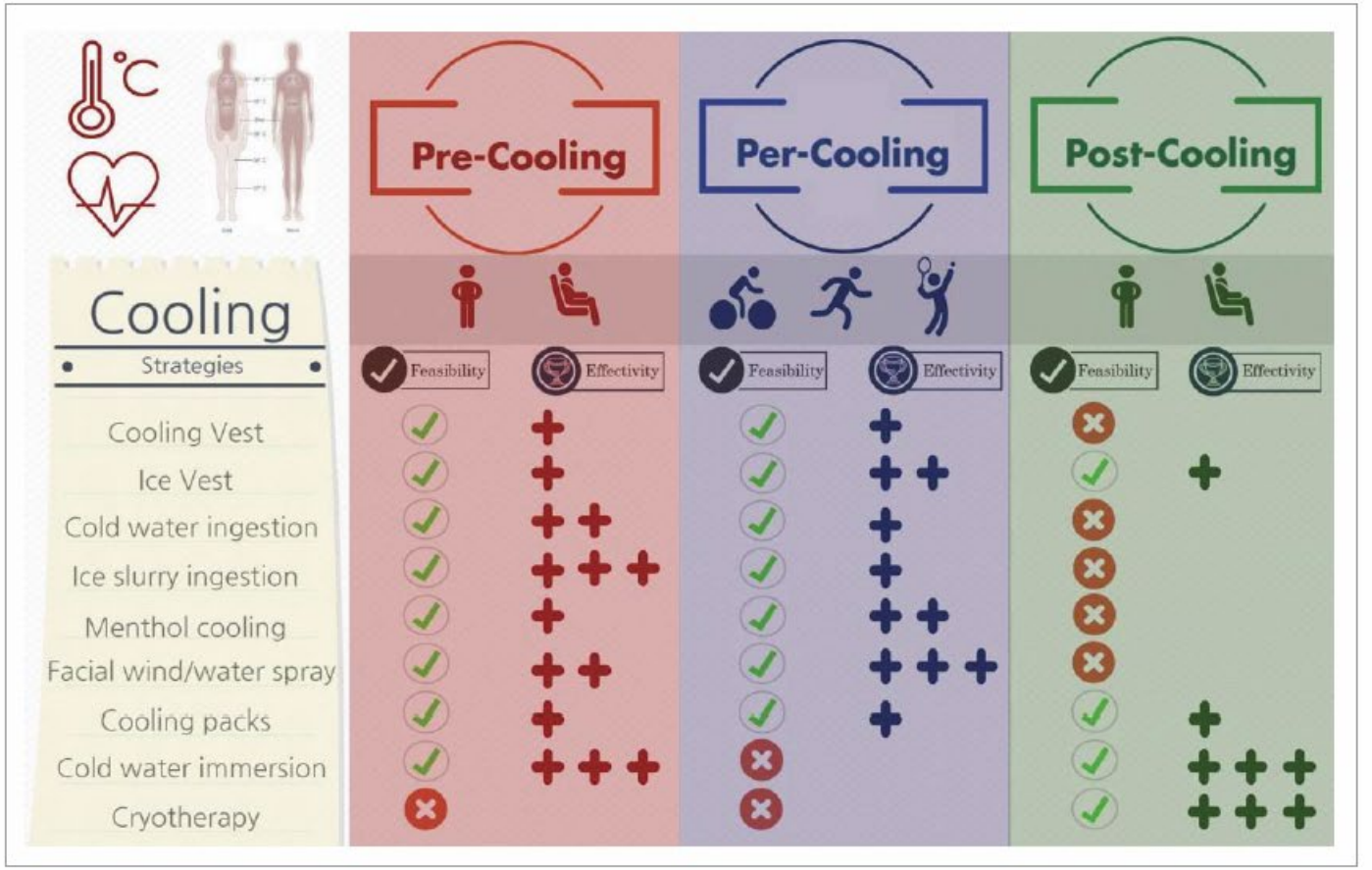

Figure 4. Infographic of the feasibility and effectivity of pre-, per- and post-cooling strategies. The effectivity of cooling techniques is classified as small (+), moderate (++) or large (+++).

Bongers et al. Temperature 2017;4(1):60–78

Pacing in the heat

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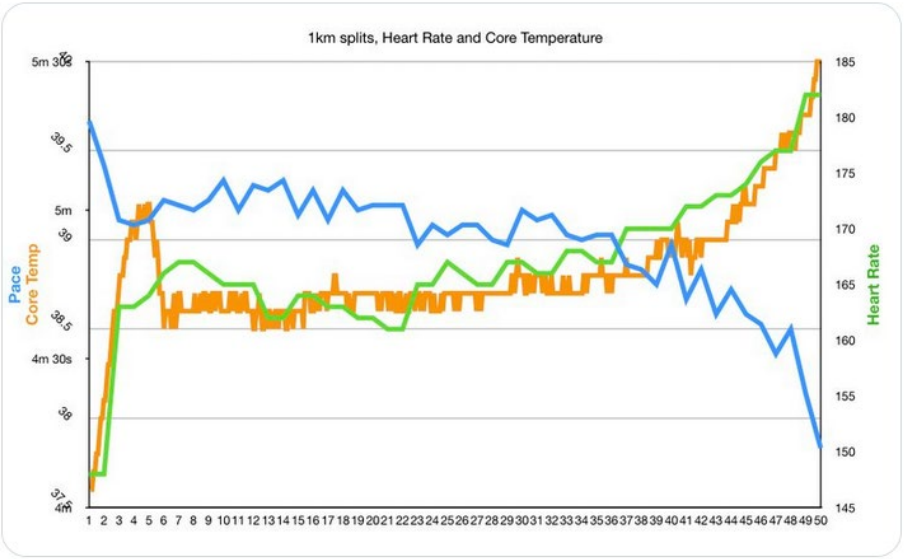
- Important in relation to optimization of performance
- In relation to individual experiences related to sensory feedback
- In the heat, balancing the metabolic heat production and maximal heat dissipation => “normal signals” are disturbed
- Maximum tolerable pace may vary more than in cooler environment
- Simulated race conditions & core temperature measurements?

Evan Dunfee after finishing third on 50 km RW in Doha:



“If I hadn’t seen the women’s marathon results and done that math and looked at those stats and convinced myself that five minutes was a fine pace to be at early in the race,” Dunfee says, “I would have just been antsy and frustrated and scared that we were going too slow.”

Fluid loss and endurance performance

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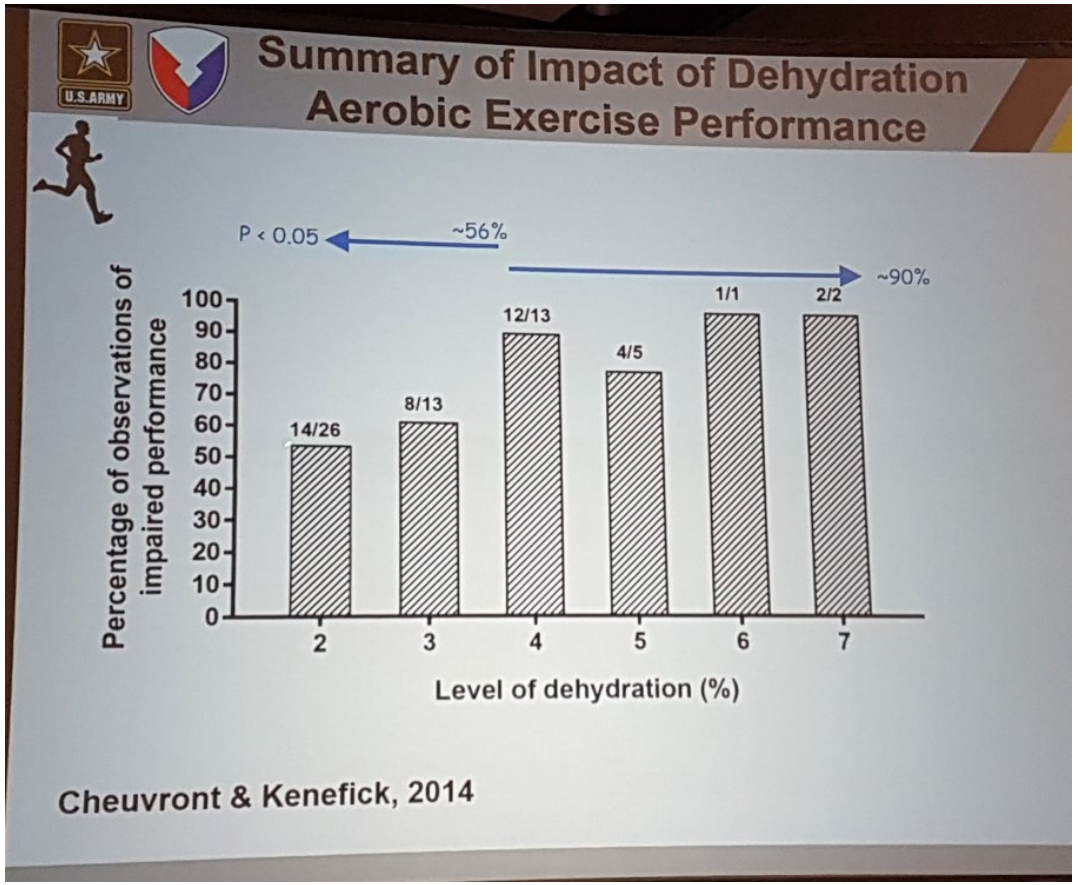
- Reduced body mass could potentially be beneficial, but…
- Already 2-3 % will make a difference, especially in the heat
- If more fluid loss, more severe effects
- Roughly 500-700 ml of water per hour may be released from metabolism for first two hours of intense exercise



Keeping the hydration in balance

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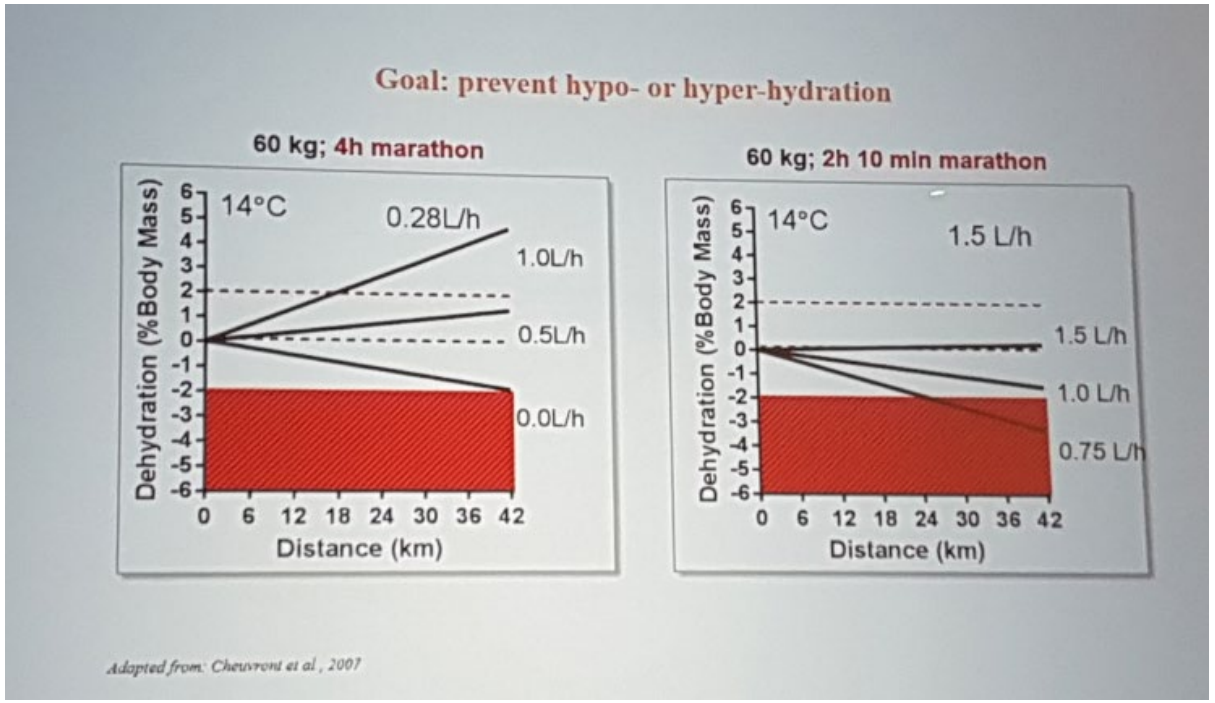
- Sweat rate may be above 2 L/h
- Max gastric emptying ~ 1.2-1.5 L/h during moderate exercise
- Exceeding the gastric emptying rate will lead to accumulation of water in the gastrointestinal tract
  - => may lead to nausea



Plasma osmolarity

- Electrolyte content in the blood may change
- Both hypo- and hypernatremia may impair performance
- Most commercial sports drinks meet the sodium requirements
- Excessive or “salty” sweaters may need extra sodium in long events in the heat

Acclima(tiza)tion to heat

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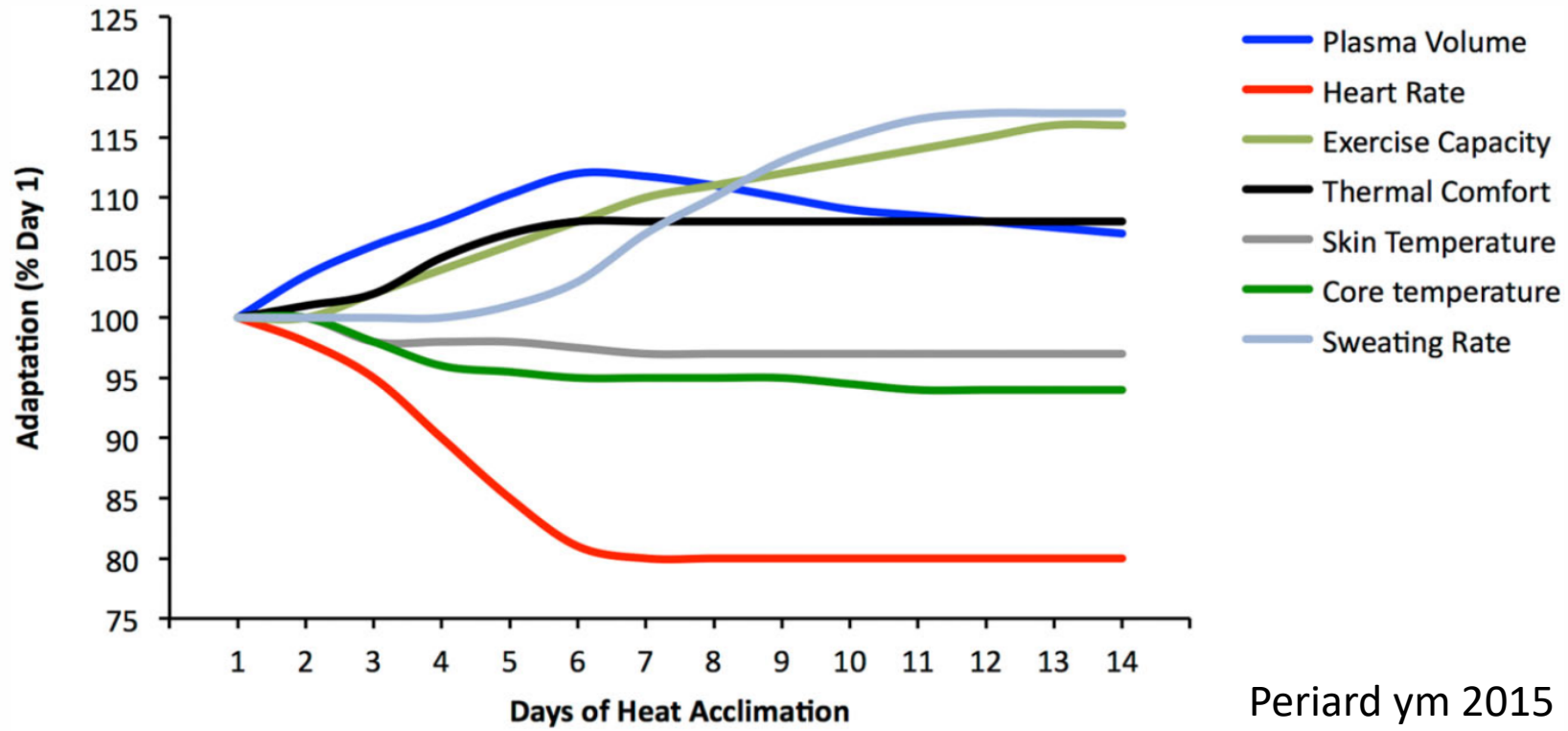
- Most of the adaptation happens during the first week of heat exposure
- Sweat response starts in lower core temperature
- Capacity of sweating increases (even doubles) in ten days
- Concentration of sodium in sweat decreases (less than 20 % of non-acclimatized values)
- Plasma volume increases (typically 4-15 %)
- Whole-body fluids increase

} Body weight ↑

- As the result body cooling increases
- Thermal comfort increases

} Performance ↑

Time course of adaptations to heat



Periard ym 2015

Fig. 5. Time course of induction in human adaptations to heat stress. Within this first week of exercise heat acclimation, plasma volume expands and heart rate decreases during exercise at a given work rate. Perceptually, the rating of thermal comfort improves. From a thermoregulatory perspective, core and skin temperature are reduced during exercise at a given work rate, whereas sweat rate increases. Consequently, aerobic exercise capacity is increased. Of note, the magnitude of these adaptations is dependent on the initial level of acclimation, the environmental conditions (i.e., dry or humid), exercise intensity, and acclimation regimen.

How much benefits from the acclimatization?

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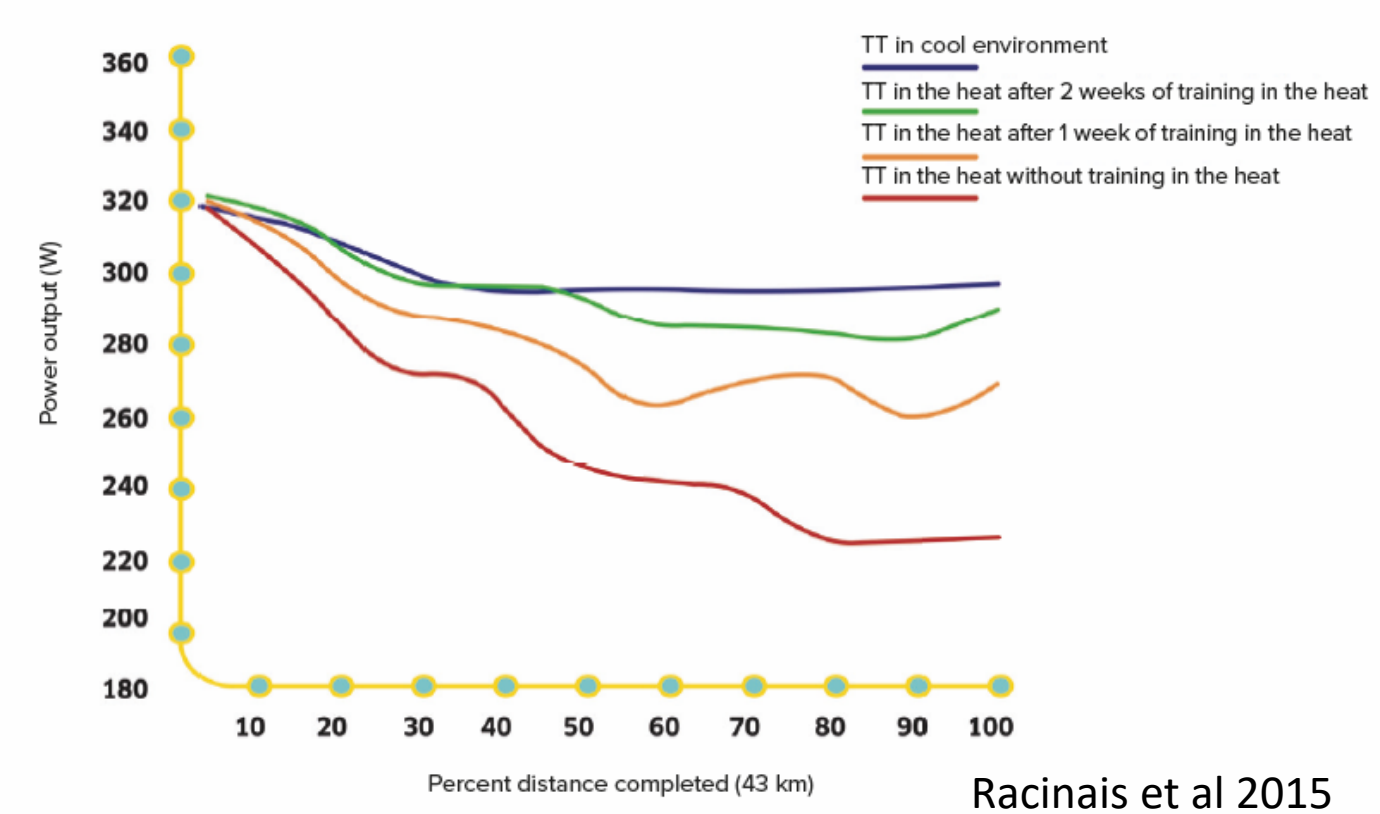
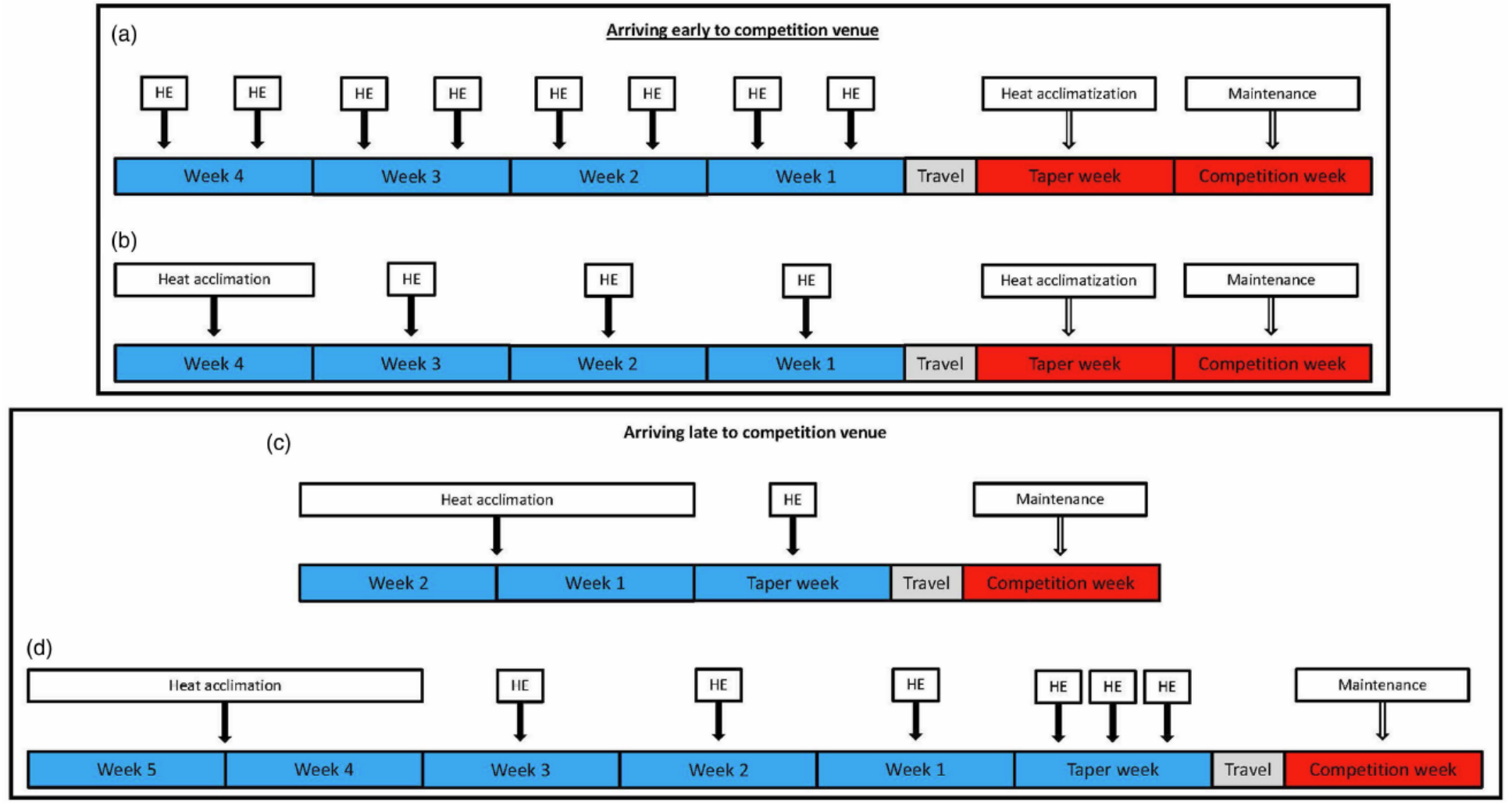
- TT in Denmark (temp 8˚C; RH 30%) before and after heat intervention
- TT in Doha (temp 34˚C; RH 18%)
- Similar multiloop, flat track including 24–27 turns in which no braking was required
- Wind speed 5-7 m/s



Racinais et al 2015

Strategies for heat adaptations

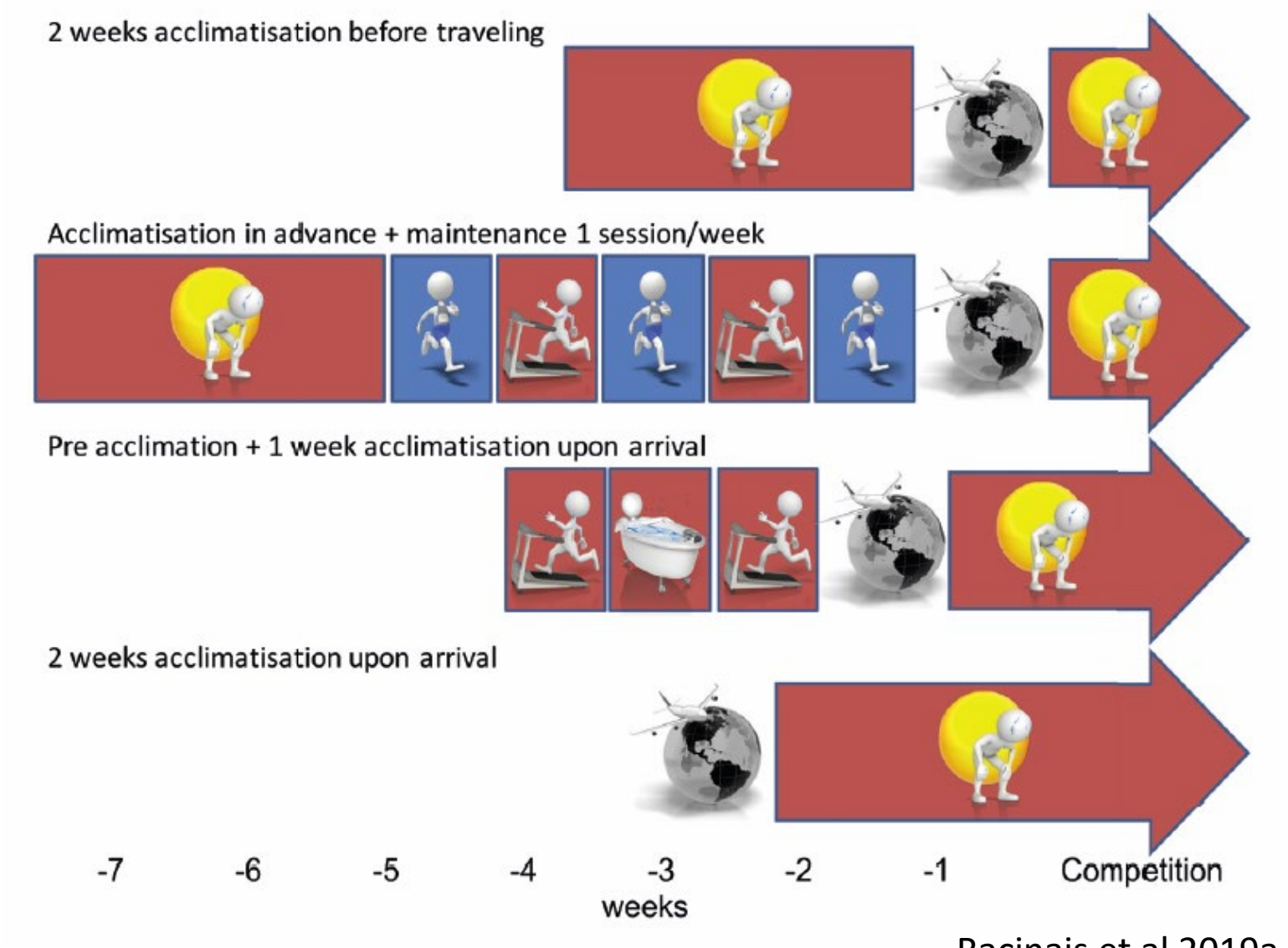


HE = Unique exposure conducting non key workout (e.g., ≥60 min, 40°C & 40% RH), or clamped heat rate protocol (e.g., 85% HR_{max}, ≥60 min, 40°C & 40% RH), or passive heating post workout in the cool (e.g., 20–45 min, sauna ~80°C or hot bath 40°C)
Heat acclimation = Daily exposures for 7–14 days of clamped heat rate protocol (e.g., 85% HR_{max}, ≥60 min, 40°C & 40% RH), or non key workouts (e.g., ≥60 min, 40°C & 40% RH), or passive heating post workout in the cool (e.g., 20–45 min, sauna ~80°C or hot bath 40°C)
Heat acclimatization = Training outdoors at the competition venue in the heat, avoiding the hottest part of the day when doing key workouts.
Maintenance = Heat acclimation/acclimatization adaptations maintained through competing and conducting training sessions in the outdoor heat.

Saunders et al 2019

In other words

KIHU

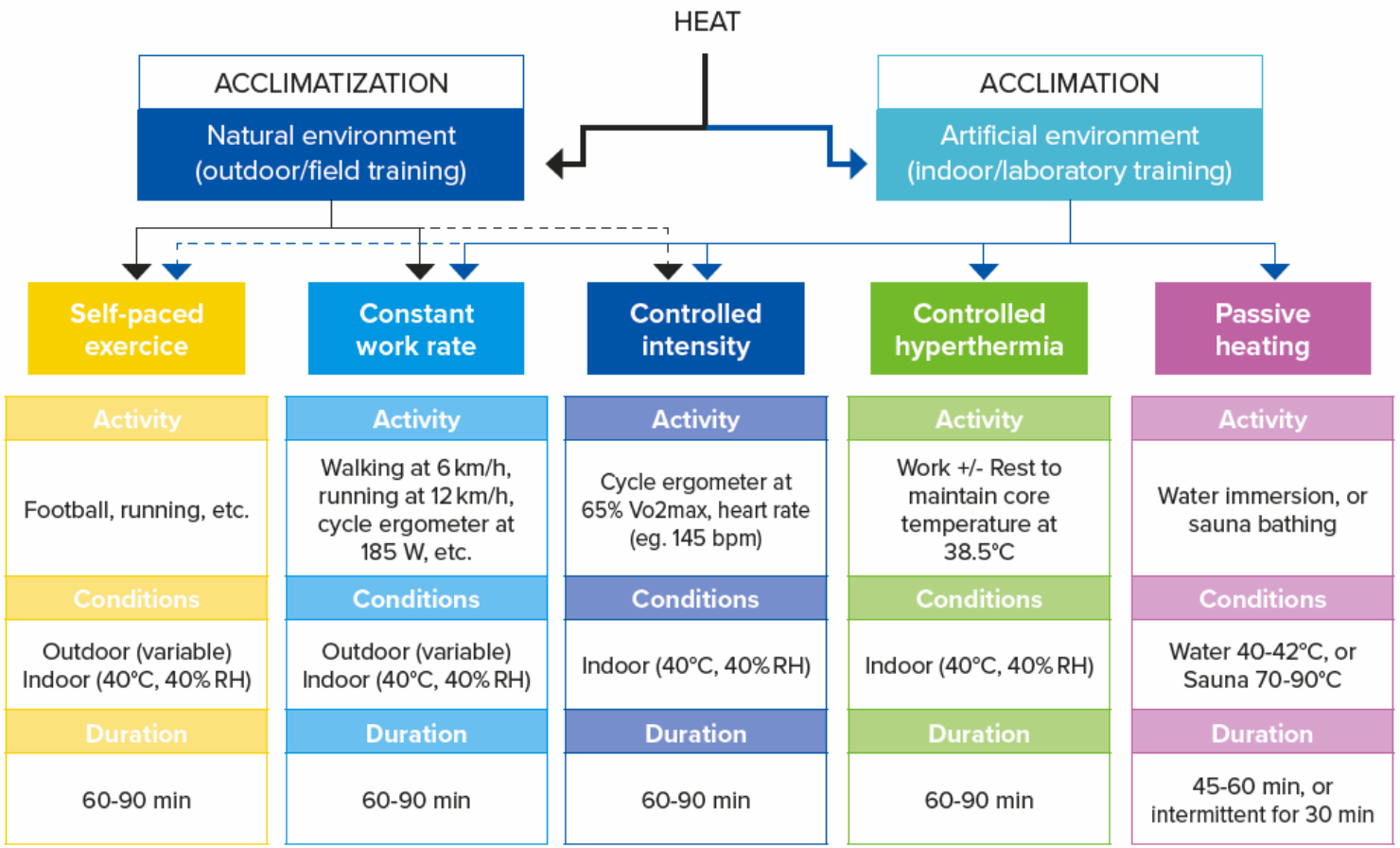


Racinais et al 2019a

What kind of training for heat acclimatization?

KIHU

The different heat acclimatisation methods[17]



Racinais et al 2019a

Body weight as a simple tool

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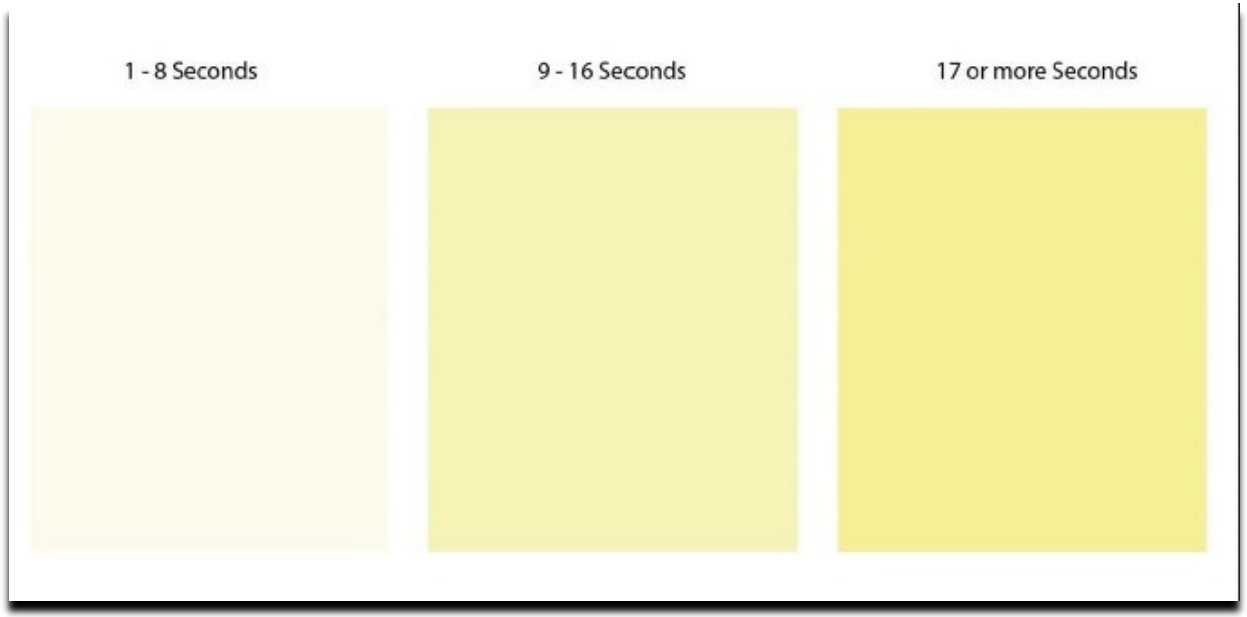
- First in the morning for follow-up
- Fast changes in body weight are reflecting the changes in total body water
- Changes in a training session
  - Weight before, during and after training
  - Amount of drinks
  - Replace the loss by 150 %

Color of urine

KIHU

- Practical indicator of hydration status
- First urine sample produced each morning
- Perhaps together with urine special gravity



Wardenaar et al 2021

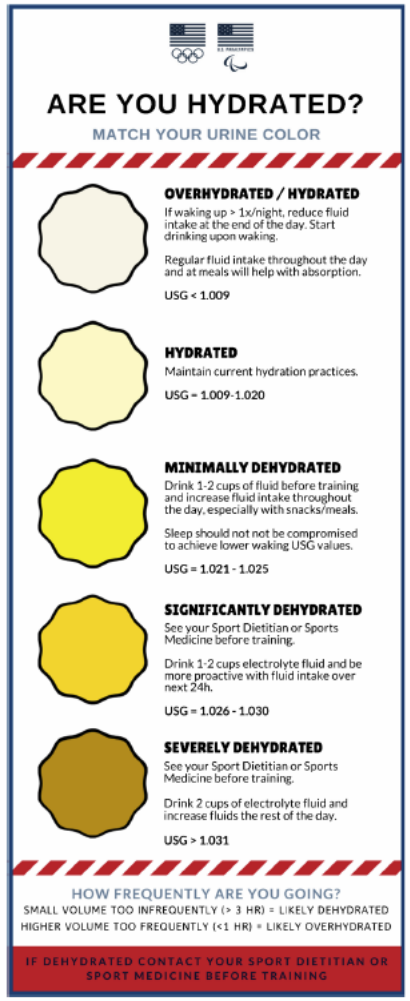


Fig. 1 Urine color chart for predicting hydration status (developed by the United States Olympic and Paralympic Committee dietitians)

Practical recommendations

KIHU

- Control your fluid balance in the heat!
  - Body weight
  - Urine color
  - Thirst

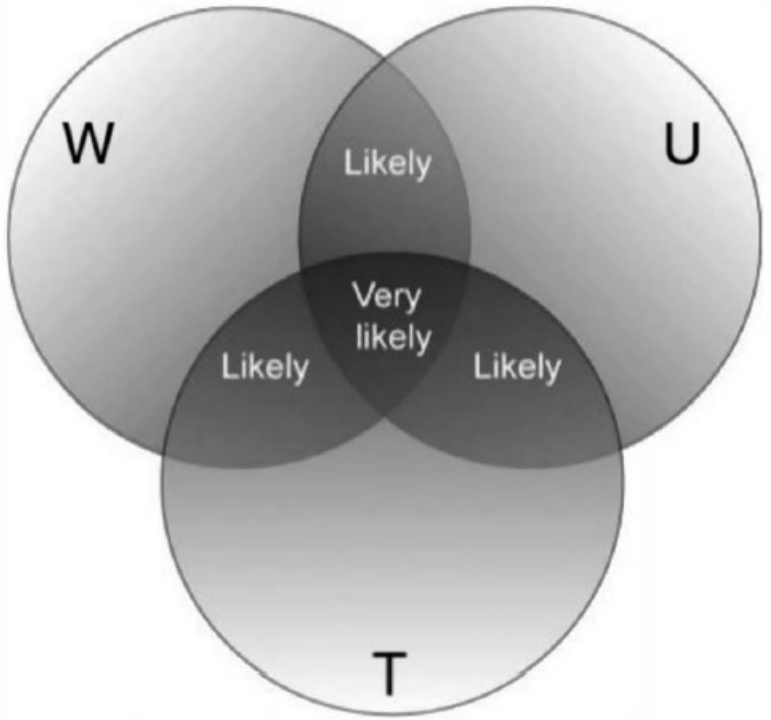
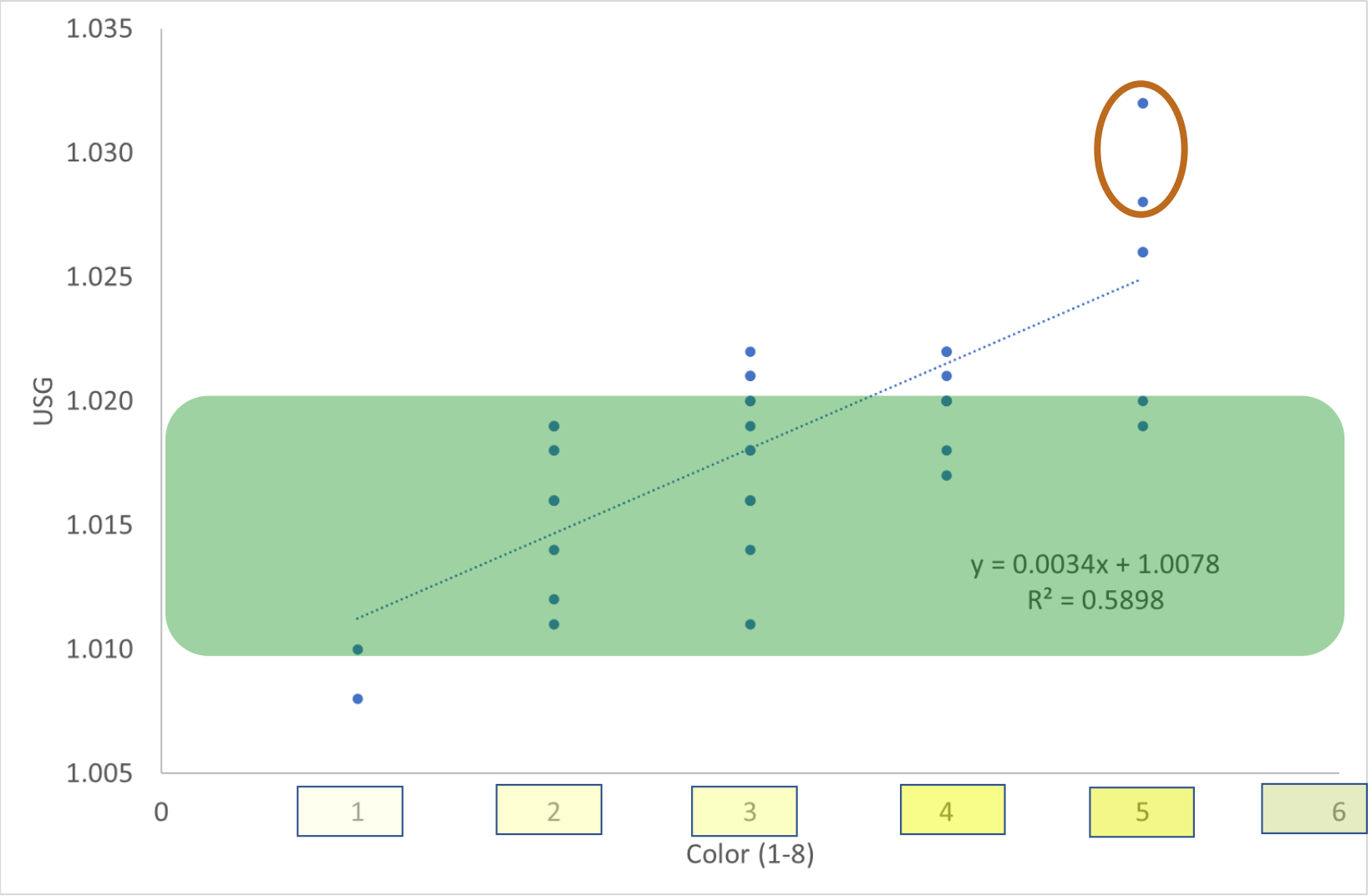
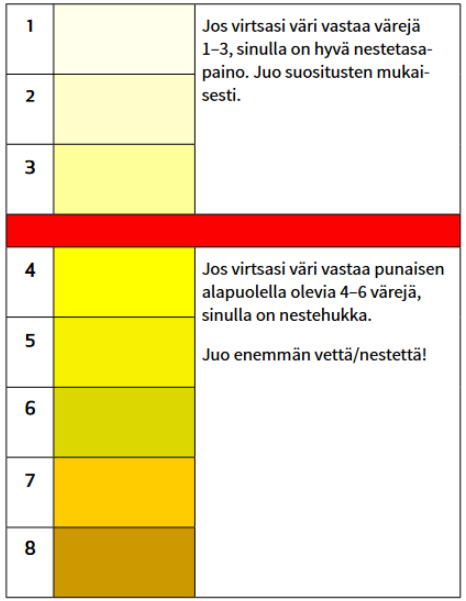


Figure 1 — The Venn diagram for athlete self-assessment of day-to-day hydration status (Cheuvront & Sawka, 2005). If two or more of the signs (W = reduced body weight, U = dark urine color, and T = feeling thirsty) are present, then correction of fluid balance is required.

Urine special gravity and color

KIHU





terveurheilija.fi

Take home message:

Give me five!

KIHU

Are you prepared to compete in 10,000 m or longer events in the heat?

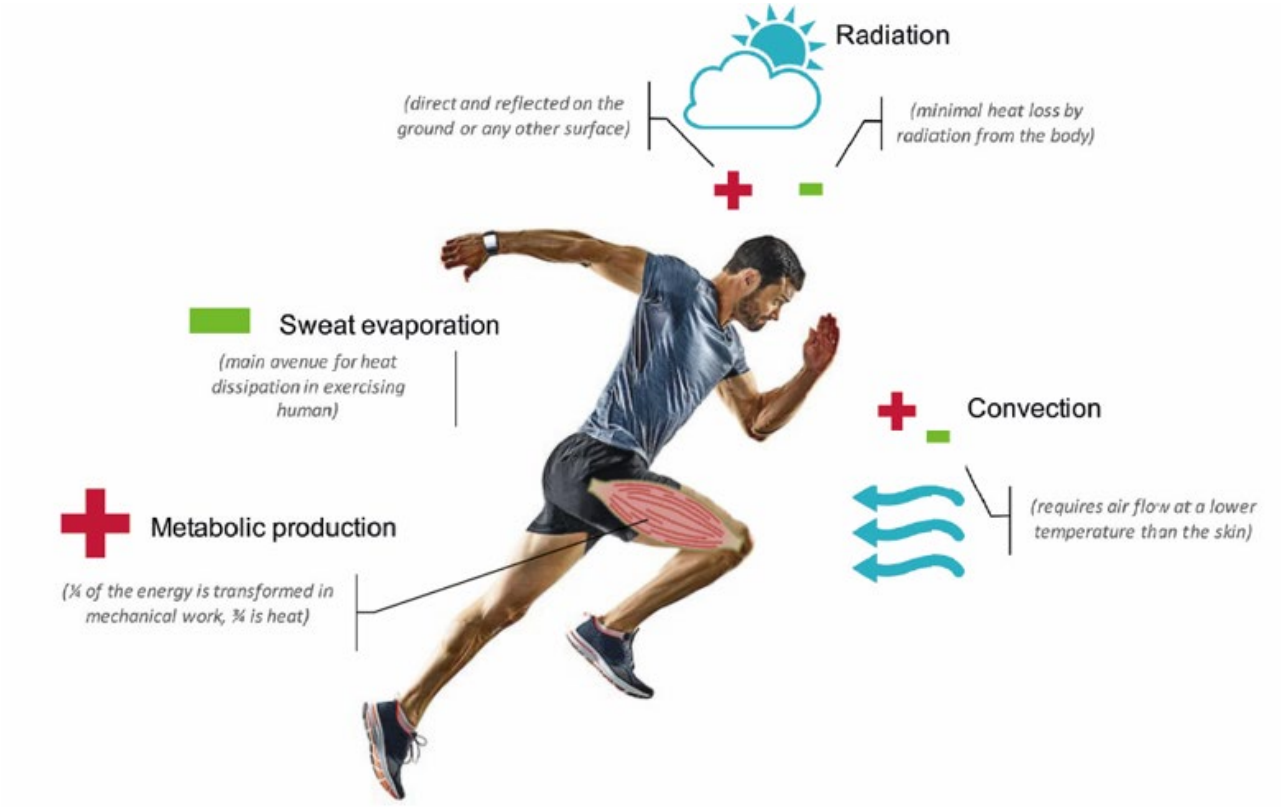
2 weeks of heat acclimatisation/acclimation	+4 points
1 week of heat acclimatisation/acclimation	+3 points
Coming from a warm country	+3 points
Hydration plan	+2 points
Pre-cooling	+1 point
Per (during)-cooling	+1 point
Clothing limiting sweat evaporation	-1 point
Previous history of heat illness	-1 point

Score at least 5 points on the above list!

Racinais et al 2019

Now, from hot to cold environment

KIHU



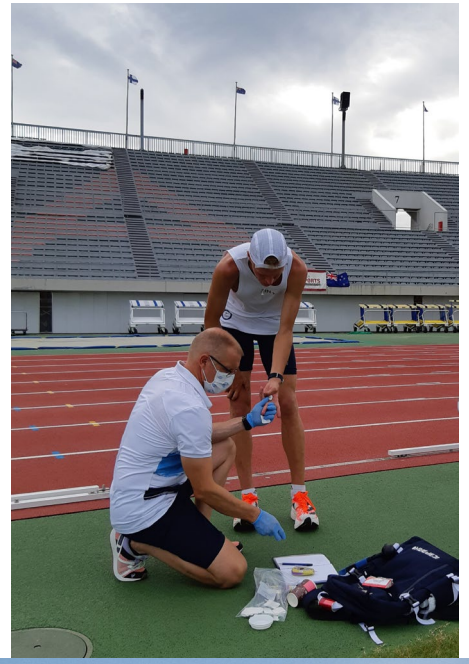


Photo: Jesse Väänänen

Training and competing in cold environment

KIHU

- Athletes in some sports are routinely exposed to cold during training and competing
- For example, FIS rules for cross country skiing competitions:

388 Cold Weather Precautions

388.1 Background

388.1.1 There are three main factors to be considered by the Jury regarding cold weather safety: the temperature; the duration of the exposure; and, the clothing and other protection against cold weather. These factors together with any other relevant information such as the "wind chill factor" must be taken into consideration when a decision is made regarding cold weather.

388.2 Between minus 15 ° and minus 25 °C

388.2.1 If the temperature level is forecast to be between minus 15 °C and minus 25 °C at any point on the course, recommendations regarding cold weather protection should be made available to the competitors. Under such conditions it is the responsibility of the competitors to seek the information and to follow the recommendations given by the organiser.

388.3 Minus 25 °C and below

388.3.1 If the temperature in a major portion of the course is minus 25 °C or below, the competition shall be delayed or cancelled.

Wind chill index

Risk of getting hypothermia and frostbite outdoors

Air temperature C

Wind speed m/s	... -10 C							-11 ... -28 C						-29 ... -39 C		
0	10	7	4	1	-2	-5	-8	-11	-14	-17	-20	-23	-26	-29	-32	-3
2	9.2	5.7	2.2	-1.3	-4.8	-8.3	-12	-15	-19	-22	-26	-29	-33	-36	-40	-43
3	8.5	4.9	1.3	-2.3	-5.9	-9.5	-13	-17	-20	-24	-28	-31	-35	-38	-42	-46
4	8	4.3	0.6	-3.1	-6.8	-10	-14	-18	-22	-25	-29	-33	-36	-40	-4	-47
5	7.6	3.8	0.1	-3.7	-7.4	-11	-15	-19	-23	-26	-30	-34	-38	-41	-45	-49
6	7.2	3.4	-0.4	-4.2	-8	-12	-16	-19	-23	-27	-31	-35	-39	-42	-46	-50
7	6.9	3.1	-0.8	-4.6	-8.5	-12	-16	-20	-24	-28	-32	-36	-39	-43	-47	-51
8	6.7	2.8	-1.1	-5	-8.9	-13	-17	-21	-25	-29	-32	-36	-40	-44	-48	-52
9	6.4	2.5	-1.5	-5.4	-9.3	-13	-17	-21	-25	-30	-33	-37	-41	-45	-49	-53
10	6.2	2.2	-1.8	-5.7	-9.7	-14	-18	-22	-26	-30	-34	-38	-42	-46	-50	-53
11	6	2	-2	-6	-10	-14	-18	-22	-26	-30	-34	-38	-42	-46	-50	-54
12	5.8	1.8	-2.3	-6.3	-10	-14	-18	-23	-27	-31	-35	-39	-43	-47	-51	-55
13	5.6	1.6	-2.5	-6.6	-11	-15	-19	-23	-27	-31	-35	-39	-43	-47	-51	-55
14	5.5	1.4	-2.7	-6.8	-11	-15	-19	-23	-27	-31	-35	-40	-44	-48	-52	-56
15	5.3	1.2	-2.9	-7	-11	-15	-19	-24	-28	-32	-36	-40	-44	-48	-52	-56
16	5.2	1	-3.1	-7.2	-11	-16	-20	-24	-28	-32	-36	-40	-45	-49	-53	-57
17	5	0.9	-3.3	-7.5	-12	-16	-20	-24	-28	-32	-37	-41	-45	-49	-53	-57
18	4.9	0.7	-3.5	-7.6	-12	-16	-20	-24	-29	-33	-37	-41	-45	-50	-54	-58
19	4.8	0.6	-3.6	-7.8	-12	-16	-20	-25	-29	-33	-37	-42	-46	-50	-54	-58
20	4.7	0.4	-3.8	-8	-12	-17	-21	-25	-29	-33	-38	-42	-46	-50	-55	-59
21	4.5	0.3	-3.9	-8.2	-12	-17	-21	-25	-29	-34	-38	-42	-46	-51	-55	-59
22	4.4	0.2	-4.1	-8.3	-13	-17	-21	-25	-30	-34	-38	-42	-47	-51	-55	-60

Low risk of hypothermia.
Risk of hypothermia, if being outdoors too long without relevant protection.
Increased risk of hypothermia. Exposed skin gets frostbitten in 10-30 min.
High risk of hypothermia. Exposed skin gets frostbitten in 5-10 min.
Exposed skin gets frostbitten in 2-5 min.
Exposed skin gets frostbitten in less than 2 min.

- Example 1:
  - Alpine skier, average speed of 80 km/h (22.2 m/s)
  - Air temperature of -14°C
  - Wind chill index -30°C, high risk of hypothermia
  - Each run is completed in less than 3 min while athlete is using protective clothing and producing metabolic heat => no problem
- Example 2:
  - XC skier, average speed of 22 km/h (6.1 m/s)
  - Air temperature of -14°C
  - Wind chill index -23°C, increased risk of hypothermia
  - Racing for 38 min (15 km), probability of frostbites in facial area is high, even with high metabolic heat production and protective clothing (*what about training for 2 hours?*)

Clothing

KIHU

- Normal skin temperature is 33°C
  - At any lower environmental temperature, heat is lost
- Air is a poor conductor of heat = good insulator, whereas water conducts heat approximately 25-fold faster than air
- With dry clothes, “micro-climate” close to the skin can easily be kept comfortable, but either sweat or rain will make it more difficult
- Water penetrates clothing more easily than snow or ice, reducing the usual insulation provided by clothing
- Use of inadequate clothing has been established in male cross-country skiers who wear thin racing suits instead of traditional winter clothing

Winter Olympics: Finnish cross-country skier suffers frozen penis in 50km race

Remi Lindholm needs a heat pack after finishing 28th

‘When it started to warm up, the pain was unbearable’

Remi Lindholm in the 50km cross country event, in which a thin suit offered little protection in the cold. Photograph: David McIntyre/Penta Press/Shutterstock

The Guardian, Feb 20th, 2022

Exercising in water

KIHU

- As water conducts heat approximately 25-fold faster than air, much higher temperatures are “cold”
- Again, the speed makes a difference
- As does the subcutaneous fat layer
- Using wet- or dry-suit reduces the rate of cooling

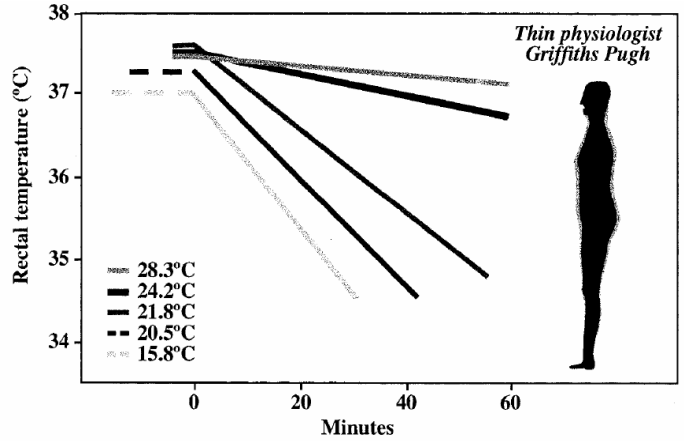


Figure 4. Changes in rectal temperature when the thin exercise physiologist swam in water at different temperatures. Note that the rate at which the rectal temperature fell increased sharply at all temperatures below 24°C. At no temperature below 28°C was the thin exercise physiologist able to maintain his body temperature when he swam. Redrawn from Pugh and Edholm (1955: 763).

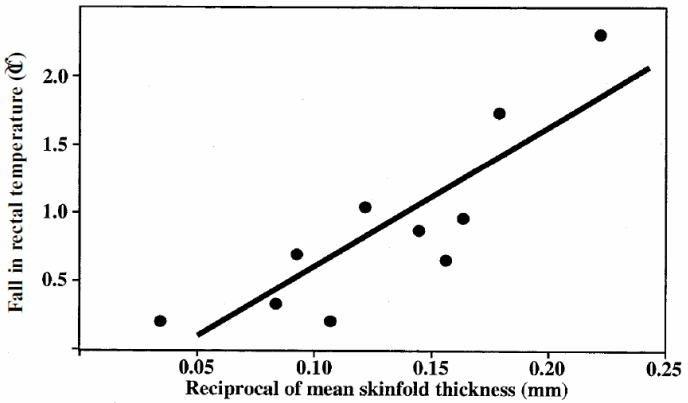


Figure 6. The linear relationship between the reciprocal of the mean skinfold thickness (a measure of body fatness) and the rate at which the rectal temperature falls on immersion in cold water. Redrawn from Keatinge (1969).

Noakes 2000

Effects of cold on exercise

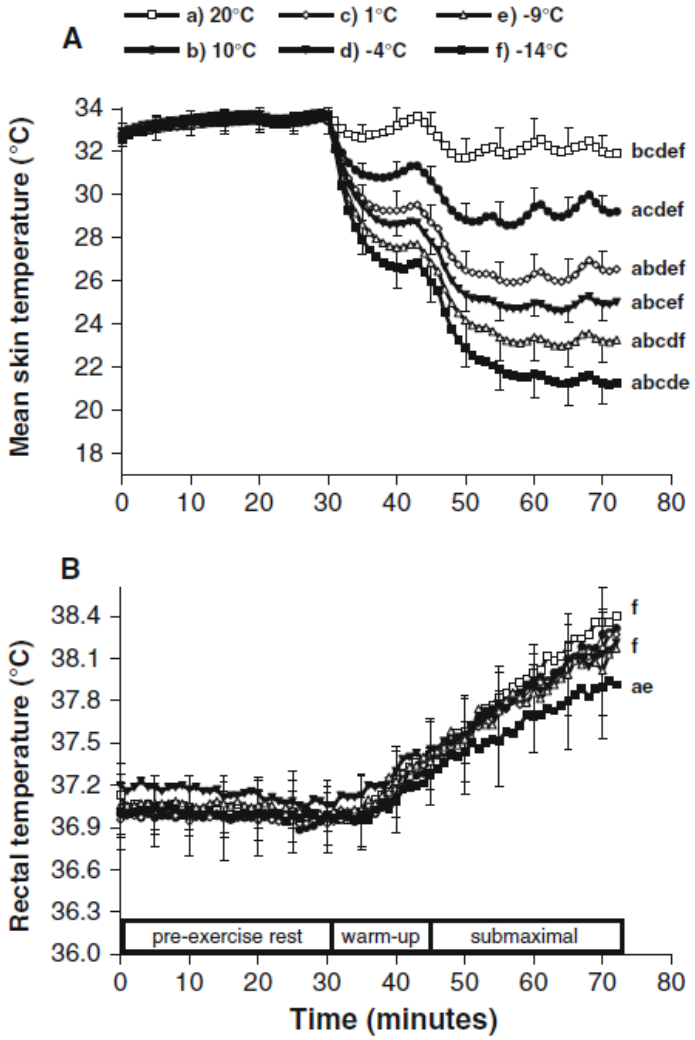
KIHU

- Cold (with or without wind) => vasoconstriction => decrease in skin temperature => decrease in muscle temperature
  - Change of 1 °C refers to 2-5 % change in performance
- Maximal contractile force is decreased
  - Movement velocity also decreased
- Respiratory exchange ratio is increased
  - Shift to carbohydrate metabolism / anaerobic energy production?
- Being ”cold-uncomfortable” in the early stages is acceptable, as metabolic heat production is increased when workout progresses
  - Avoiding excessive sweating
- How to warm-up and how to keep athletes warm between warm-up and the start of the race?

Gatterer et al 2021

Thin racing suit, temperature and endurance performance

KIHU



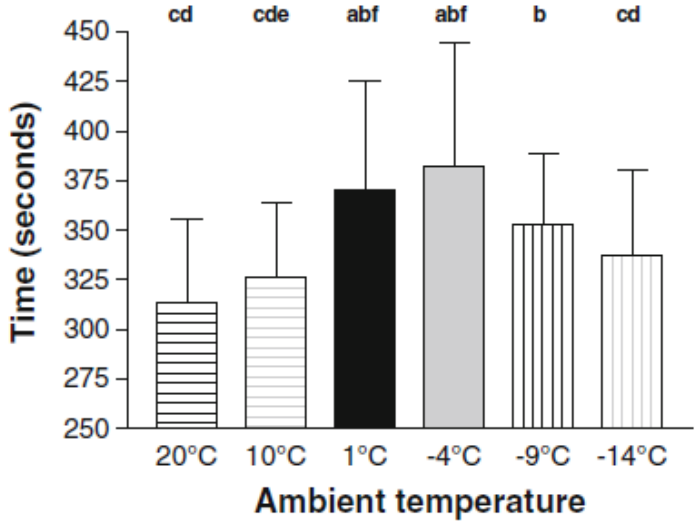


Fig. 3 Time to exhaustion (TTE, $n = 7$) at the six ambient conditions. The *letters a, b, c, d, e, f* indicate a significant difference in TTE between ambient conditions ($P < 0.05$) from corresponding values at 20, 10, 1, −4, −9 and −14 °C, respectively. Values are expressed as mean ± SD

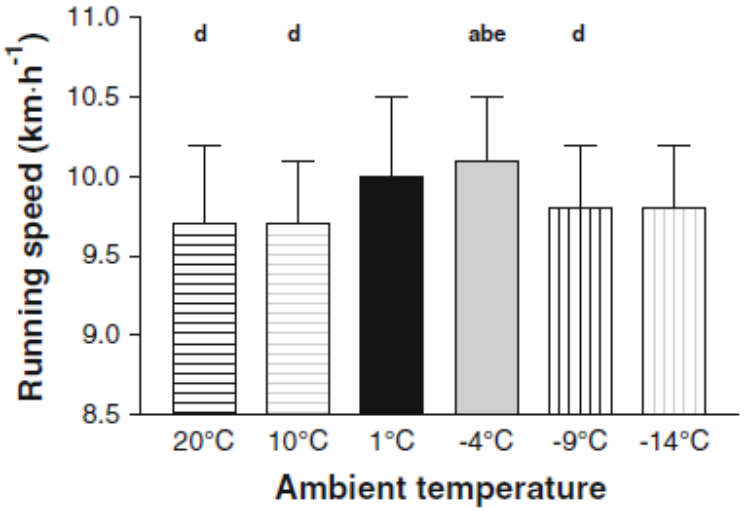


Fig. 5 Running speed at lactate threshold. Values are expressed as mean ± SD

Sandsund et al 2012

Cold exposure summary

KIHU

- Hypothermia / frostbites are very unlikely for athletes wearing wind protective clothing and competing in typical weather conditions
- Risk may be higher if fatigued / overtrained
- Increased ventilation during training and competing in cold may result airway inflammation => increased prevalence of EIA and BHR
- Symptoms occur more frequently after closely repeated competitions, exacerbations caused often by respiratory viral infections

- Protect yourself and don’t compete with a respiratory tract infection!

Practical recommendations

KIHU

- Pay attention to weather conditions
- Remember wind chill index
- Protection equipment (clothes / mask)
- Regular medical follow-up
- Correct treatment for EIA / BHR
  - Note WADA regulations!

Picture: Teemu Lemmettylä

- Especially, don’t be stupid and compete with a respiratory tract infection!

KISS – Keep It Simple, Scientist

KIHU

- Training & competition in the heat
  - Get used to it (+ cool down)!
- Training & competition in the cold
  - Put some more clothes (+ other protection) on!

References / recommended reading

KIHU

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