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RESEARCH
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SPORT & EXERCISE

Heat tolerance testing: Moving on beyond a single test

Associate Professor Julien Périard

BSc (Hons), BEd, MA, PhD, FECSS



@DrJPeriard

Heat illness – Defence force



Report: Extreme heat a grave threat for military bases

At least 17 people have died of heat exposure while training at bases since 2008

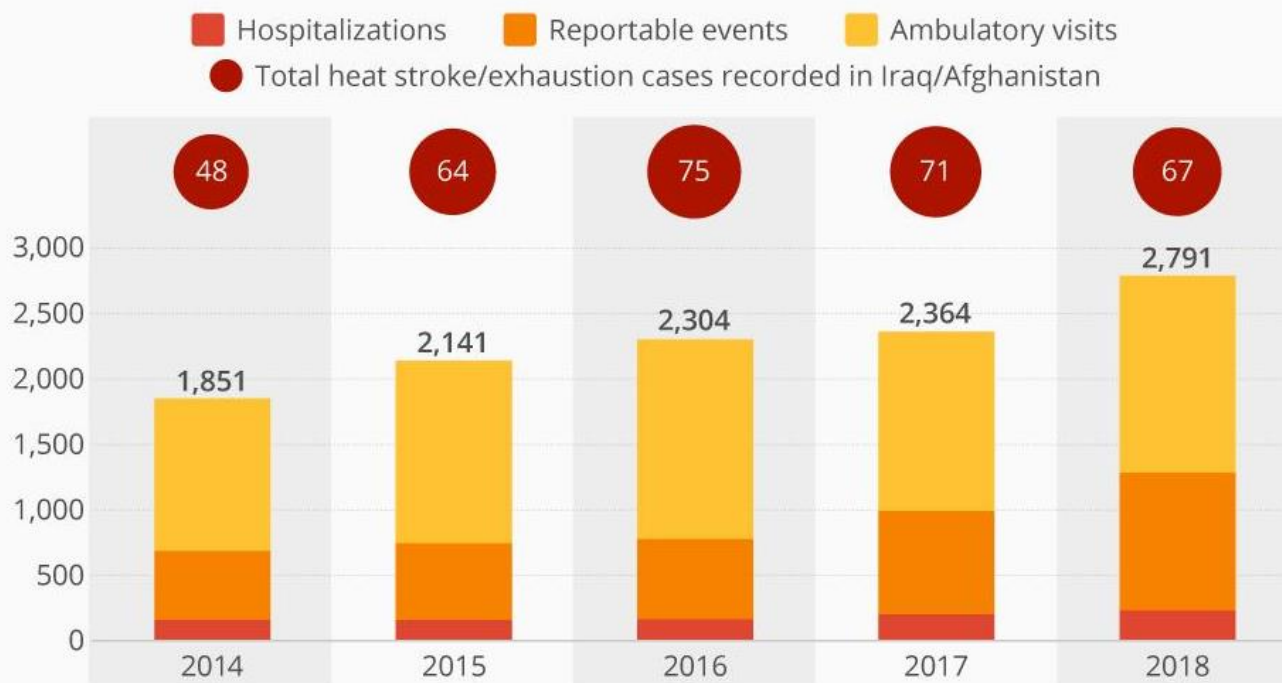
The U.S. Military Is Experiencing More Cases Of Illness From Extreme Heat

How rising temps could cause even more heat casualties at military bases

Heat illness – Defence force

The U.S. Military Is Experiencing More Heat-Related Illnesses

Total number of heat stroke/exhaustion cases in the U.S. military by year



@StatistaCharts Source: Health.mil

Forbes statista

Heat illness – Defence force



Australian Government
Department of Defence
Defence People Group

Defence People Policy, SafetyMan

- Managing Personnel Exposure To Excessive Heat/Cold
- Managing ADF Cadet Exposure To Excessive Heat

Outline

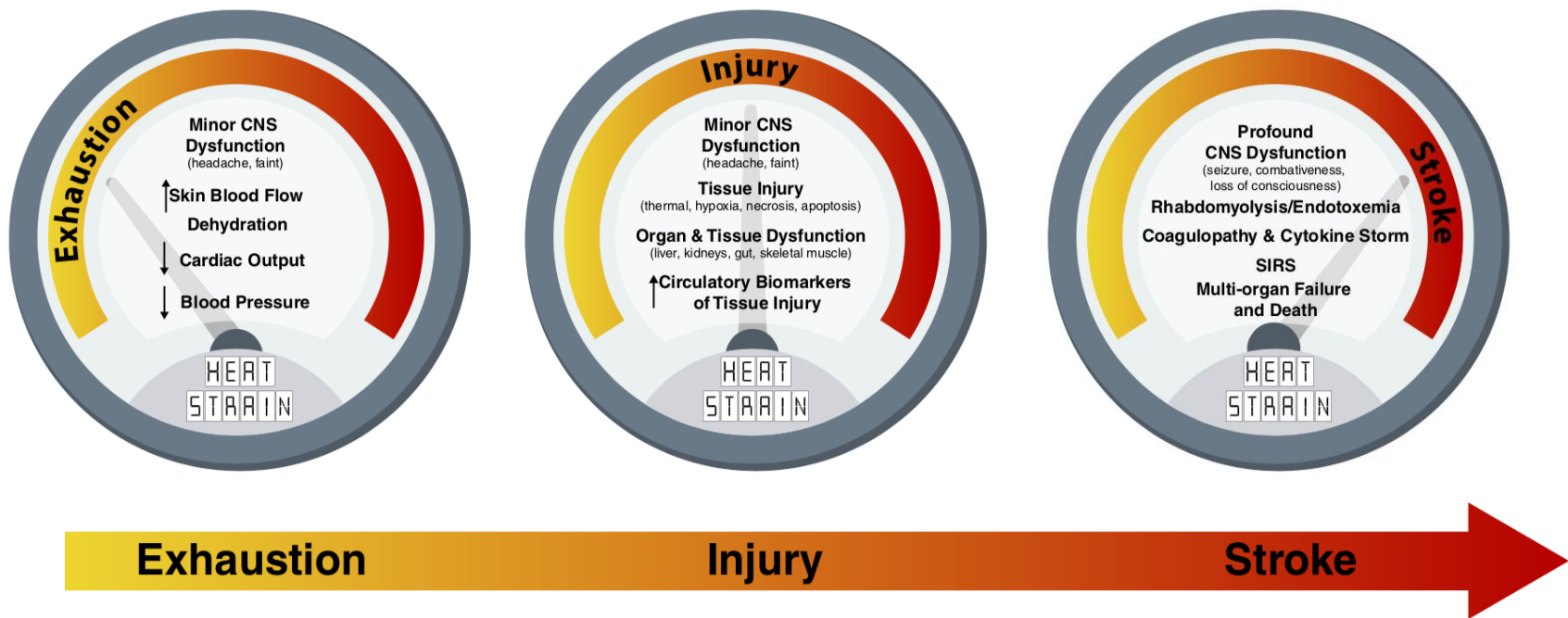
- Exertional heat illness
 - Heat illness continuum
 - Risk factors
 - Heat exchange
 - Physical activity in military uniforms
- Heat tolerance test
 - Protocol and parameters
- Beyond one test
 - Improving the outcome
 - Recommendations



Exertional heat illness



Exertional heat illness – Continuum



Exertional heat illness – Risk factors

Risk factor	Effect
<p>➔ <i>Compromised Health Status</i></p> <ul style="list-style-type: none"> Viral or bacterial infection Fever Skin disorders Cardiovascular insufficiency 	<ul style="list-style-type: none"> Augmented hyperthermic response; immunocompromised Augmented hyperthermic response Local inflammation; impaired sweating Orthostatic intolerance
<p>➔ <i>Environmental factors</i></p> <ul style="list-style-type: none"> Heat waves High humidity Lack of air movement Urban heat islands Lack of air conditioning 	<ul style="list-style-type: none"> Prolonged environmental heat exposure Impedes evaporative cooling Impedes convective cooling Higher intensity, longer duration environmental heat exposure Impedes evaporative, convective cooling
<p>➔ <i>Medications (classic)</i></p> <ul style="list-style-type: none"> Diuretics Anticholinergics (Atropine) β-blockers (Propranolol) Antihistamines Antidepressants Alcohol NSAIDs (Aspirin, Acetaminophen) 	<ul style="list-style-type: none"> Dehydration and salt, potassium and calcium depletion Impaired sweating Reduced blood pressure; reduced skin blood flow Impaired sweating Increased heat production Diuresis, impaired vasomotor reflexes Increased gut and liver toxicity
<p>➔ <i>Drug Use (Exertional)</i></p> <ul style="list-style-type: none"> Ergogenic aids (Ephedrine) Ecstasy (MDMA) Ritalin NSAIDs (Aleve) 	<ul style="list-style-type: none"> Increased activity and heat production, impaired sweating Increased heart rate and blood pressure; sweating or chills; increased muscle tension Increased heart rate and blood pressure; excessive sweating Increased gut and liver toxicity
<p>➔ <i>Genetic conditions</i></p> <ul style="list-style-type: none"> Malignant hyperthermia TLR4 polymorphisms 	<ul style="list-style-type: none"> Increased metabolic heat production Endotoxin hyporesponsiveness

NSAIDs, nonsteroidal anti-inflammatory drugs; MDMA, 3,4-methylenedioxymethamphetamine; TLR, toll-like receptor.

Heat exchange

Radiation

Heat transfer via electromagnetic waves

Conduction

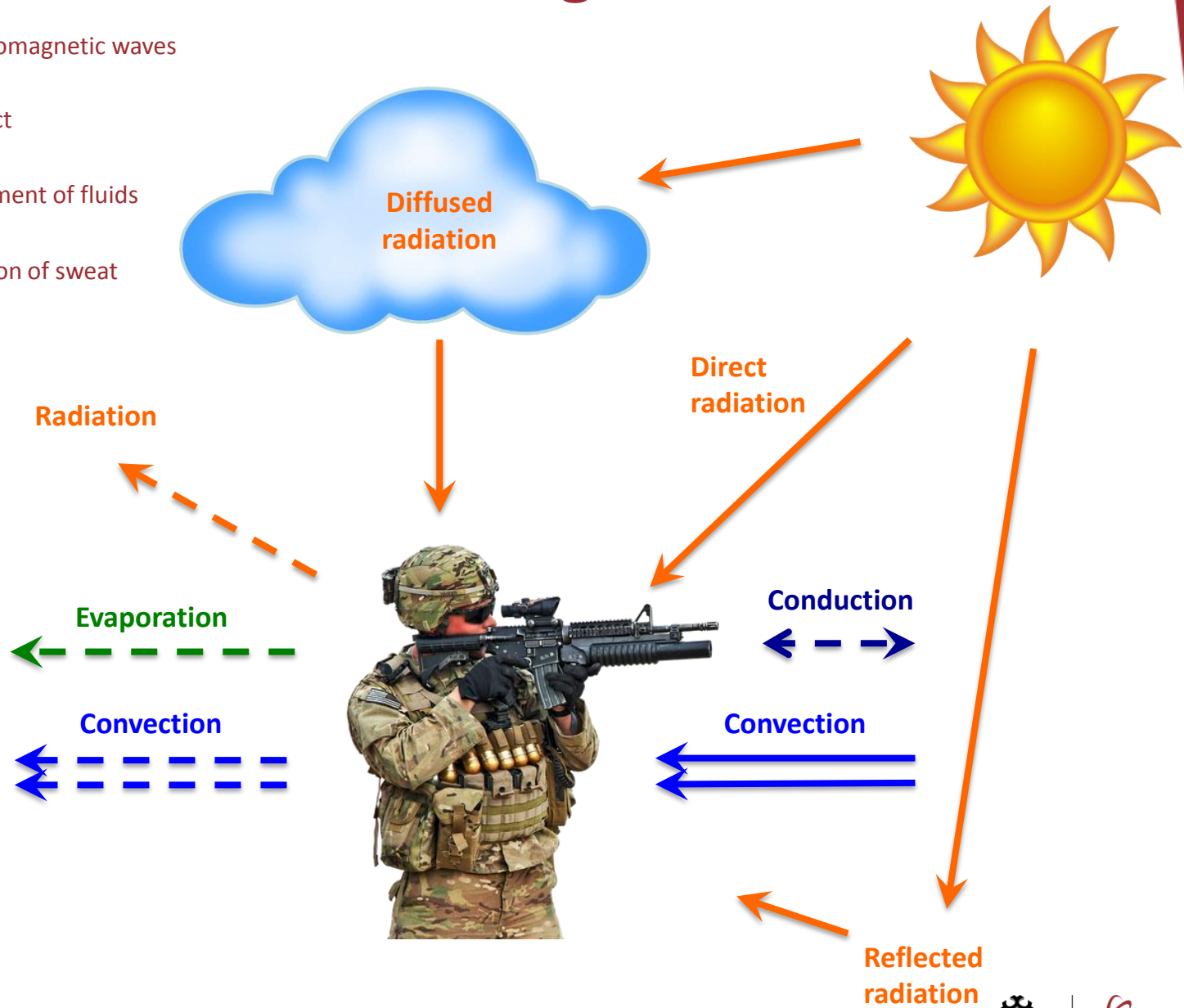
Heat transfer via contact

Convection

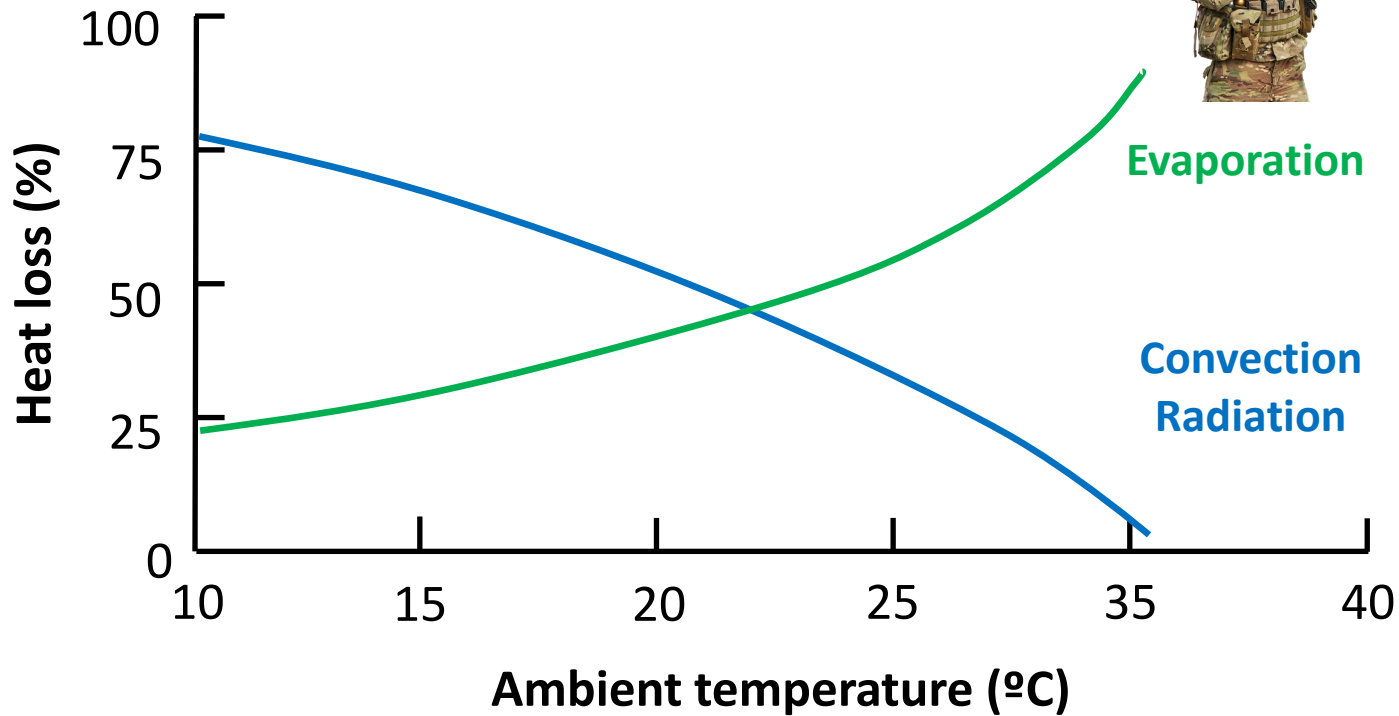
Heat transfer via movement of fluids

Evaporation

Heat loss via vaporization of sweat



Heat exchange – Evaporation

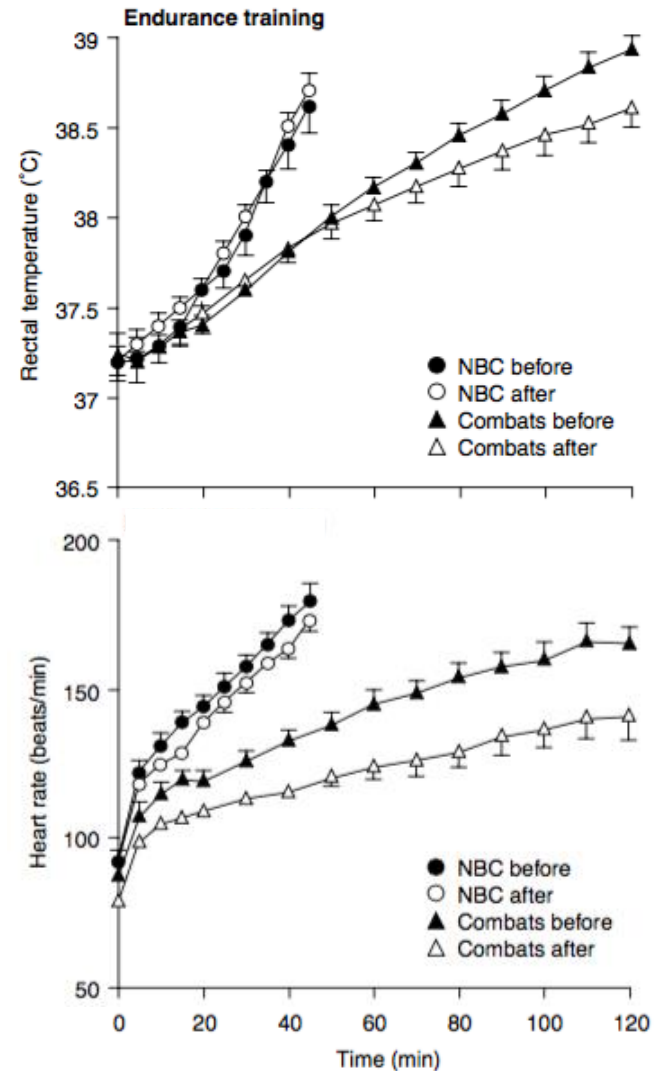


Physical exertion in the heat

Uncompensable heat stress



- Walking at 4.8 km/h, 2% grade in 40°C, 30% RH
- Before and After 8 weeks of endurance training



Heat tolerance test



Heat tolerance test – Protocol

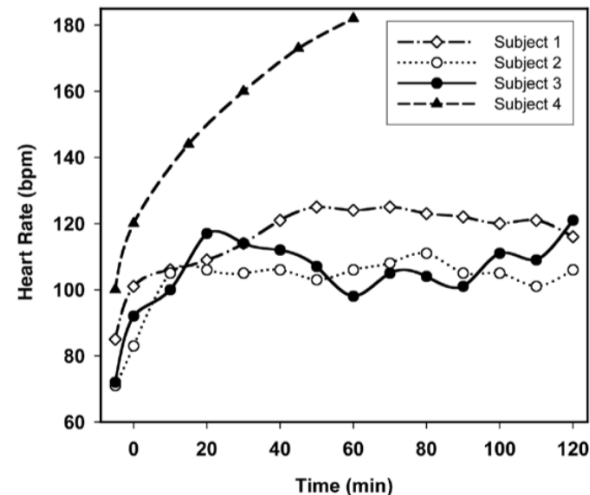
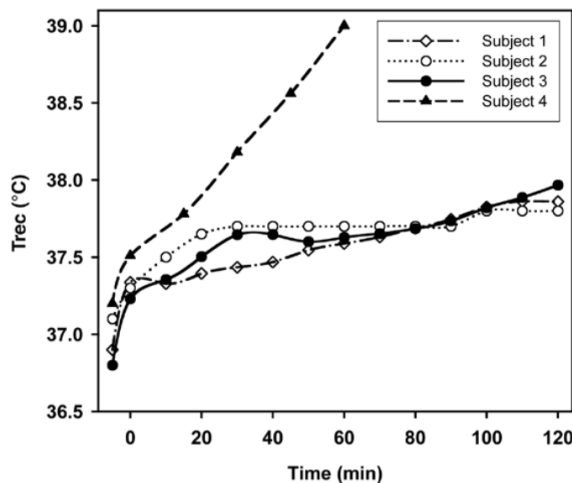
Israeli Defense Force - Heat Tolerance Test

- Walking for 2 h at 5 km/h and 2% incline
- 40°C and 40% RH



Key outcomes:

- Core temperature rise with tendency to plateau <38.5°C
- Heart rate increase with tendency to plateau <150 bpm
 - Classified as heat tolerant or intolerant
- Sweat rate between 0.5 and 1.2 L/h – Thermal balance



Heat tolerance test – Guidelines

- Performed a few weeks after clinical recovery from heat illness episode
- First failure → Individual considered heat intolerant
 - Repeat test 2 to 3 months later
- Second failure → Definitive indication of heat intolerance
 - Discontinuation of active combat duty
 - Return to unsupervised recreational activity permitted

Heat Tolerance in Women—Reconsidering the Criteria

DRUYAN A, MAKRANZ C, MORAN D, YANOVICH R, EPSTEIN Y, HELED Y.
Heat tolerance in women—reconsidering the criteria. Aviat Space Environ Med 2012; 83:58–60.



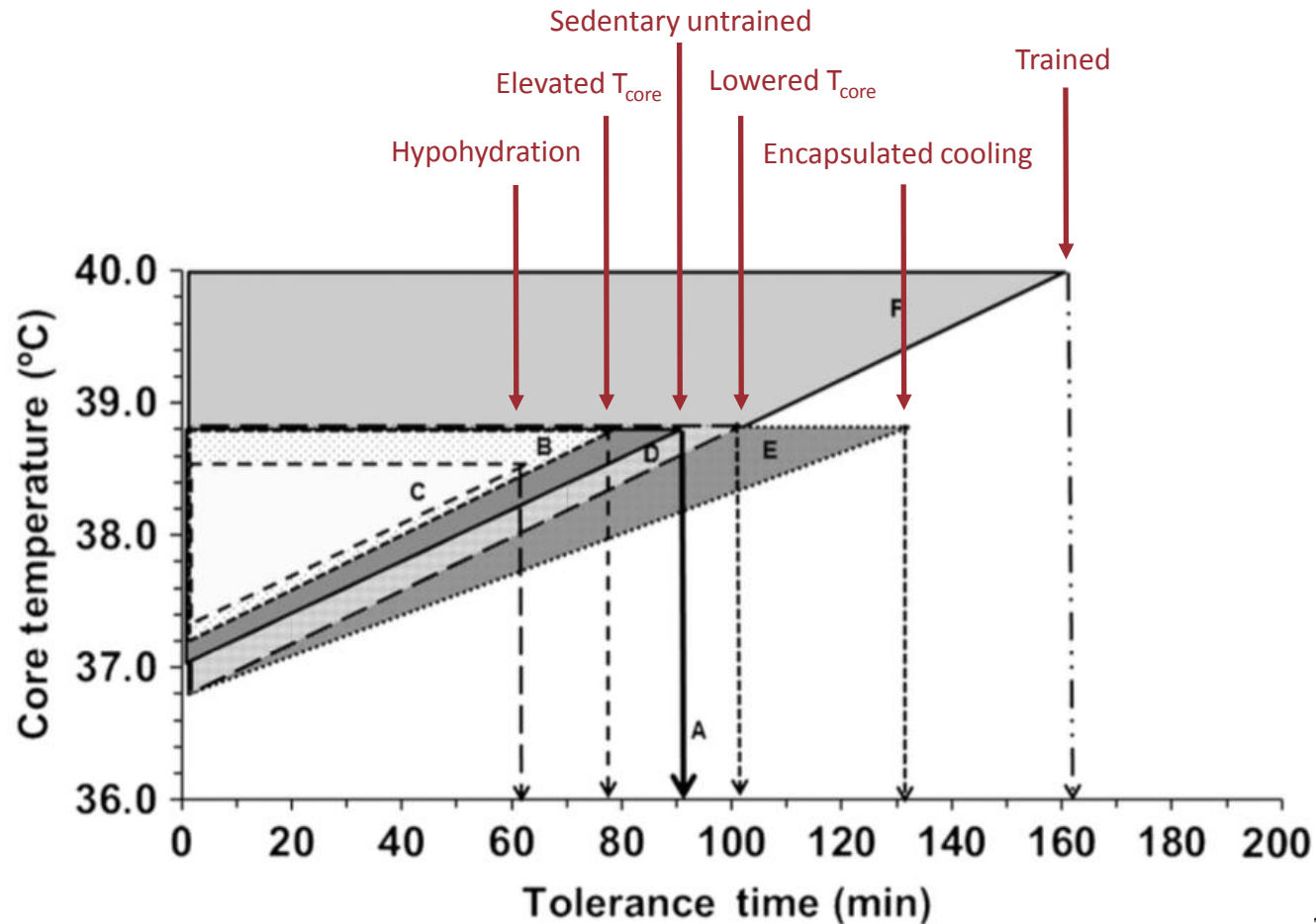
- Heat intolerance rate
 - Men: 26%
 - Women: 68%
- Aerobic fitness, lower sweat rates, different hormonal profile, and different morphology

Beyond one test

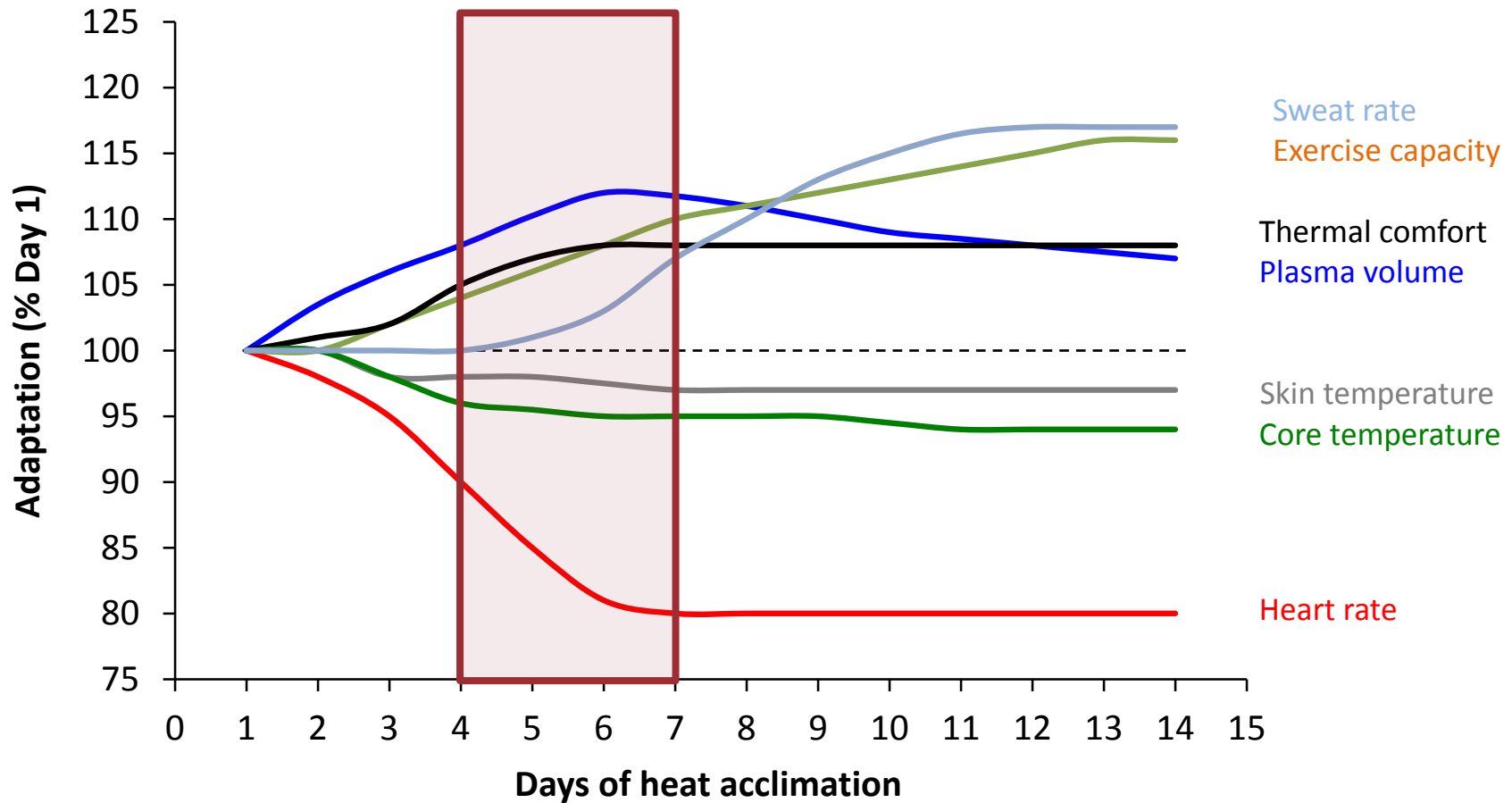


Training and heat acclimation

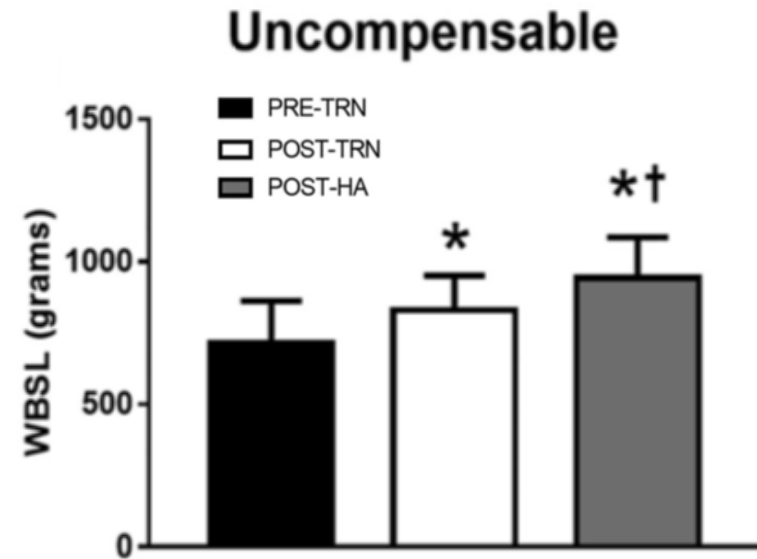
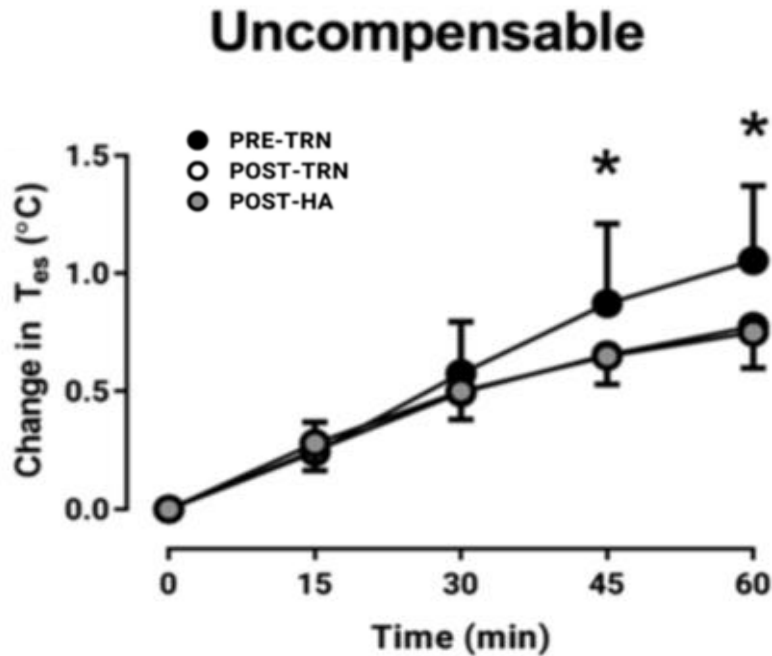
Light exercise in uncompensable heat stress



Heat acclimation

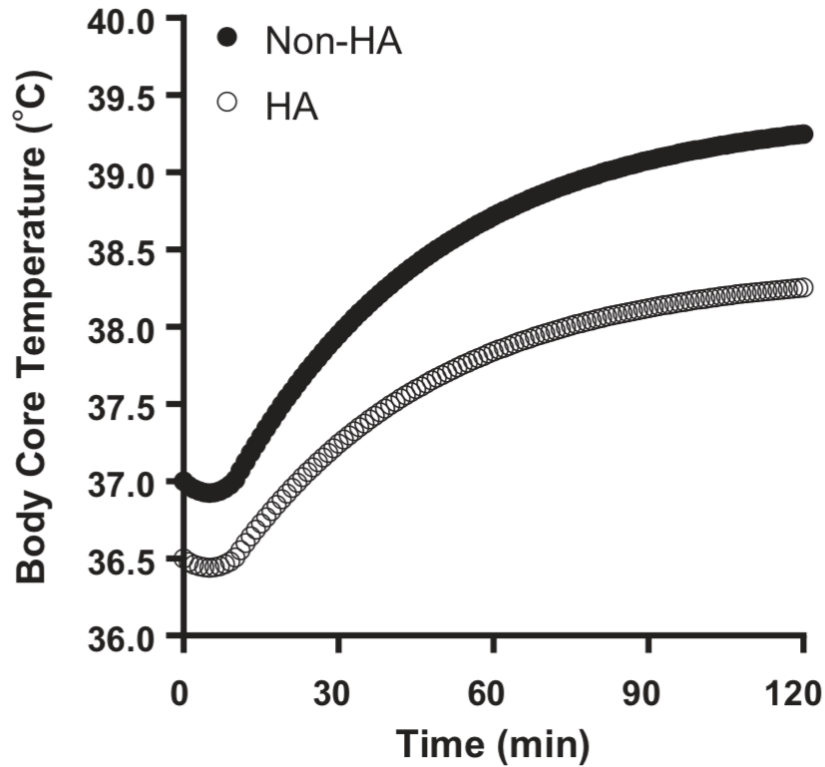


Training and heat acclimation



- 8 weeks of aerobic training
- 6 days of heat acclimation

Training and heat acclimation



Recommendations

Conduct initial $\text{VO}_{2\text{max}}$ test

FEMALE

(values in ml/kg/min)

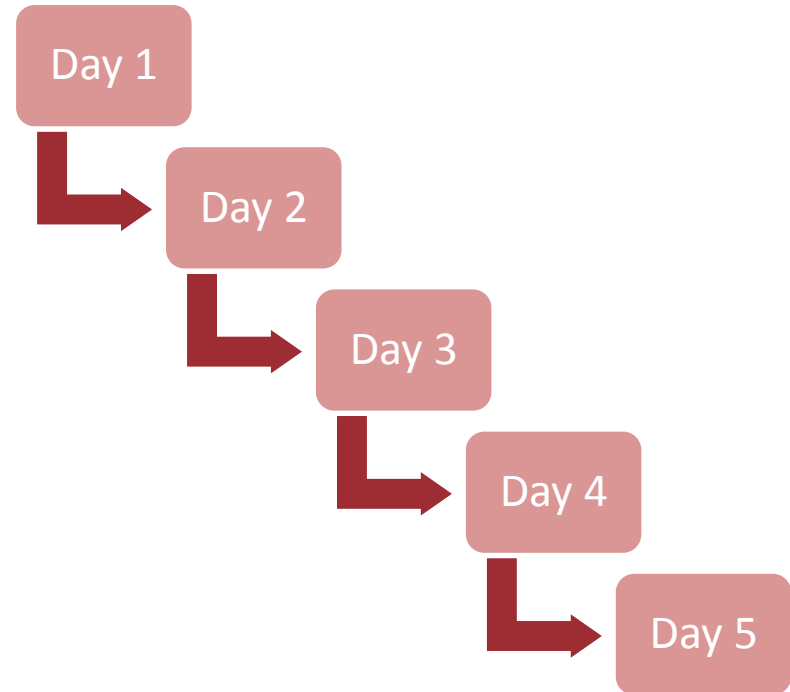
Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<25.0	25.0 - 30.9	31.0 - 34.9	35.0 - 38.9	39.0 - 41.9	>41.9
20-29	<23.6	23.6 - 28.9	29.0 - 32.9	33.0 - 36.9	37.0 - 41.0	>41.0
30-39	<22.8	22.8 - 26.9	27.0 - 31.4	31.5 - 35.6	35.7 - 40.0	>40.0
40-49	<21.0	21.0 - 24.4	24.5 - 28.9	29.0 - 32.8	32.9 - 36.9	>36.9
50-59	<20.2	20.2 - 22.7	22.8 - 26.9	27.0 - 31.4	31.5 - 35.7	>35.7
60+	<17.5	17.5 - 20.1	20.2 - 24.4	24.5 - 30.2	30.3 - 31.4	>31.4

MALE

(values in ml/kg/min)

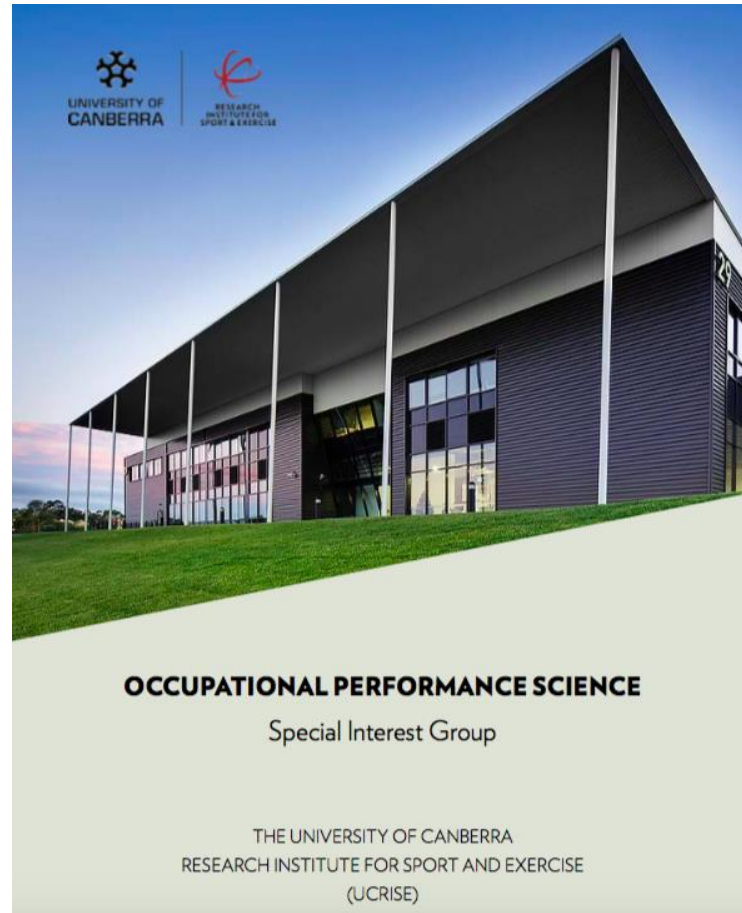
Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<35.0	35.0 - 38.3	38.4 - 45.1	45.2 - 50.9	51.0 - 55.9	>55.9
20-29	<33.0	33.0 - 36.4	36.5 - 42.4	42.5 - 46.4	46.5 - 52.4	>52.4
30-39	<31.5	31.5 - 35.4	35.5 - 40.9	41.0 - 44.9	45.0 - 49.4	>49.4
40-49	<30.2	30.2 - 33.5	33.6 - 38.9	39.0 - 43.7	43.8 - 48.0	>48.0
50-59	<26.1	26.1 - 30.9	31.0 - 35.7	35.8 - 40.9	41.0 - 45.3	>45.3
60+	<20.5	20.5 - 26.0	26.1 - 32.2	32.3 - 36.4	36.5 - 44.2	>44.2

Repeat Heat Tolerance Test

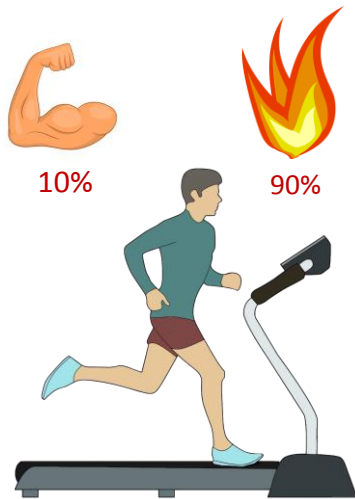


Aerobic fitness – Acclimation status – Heat tolerance

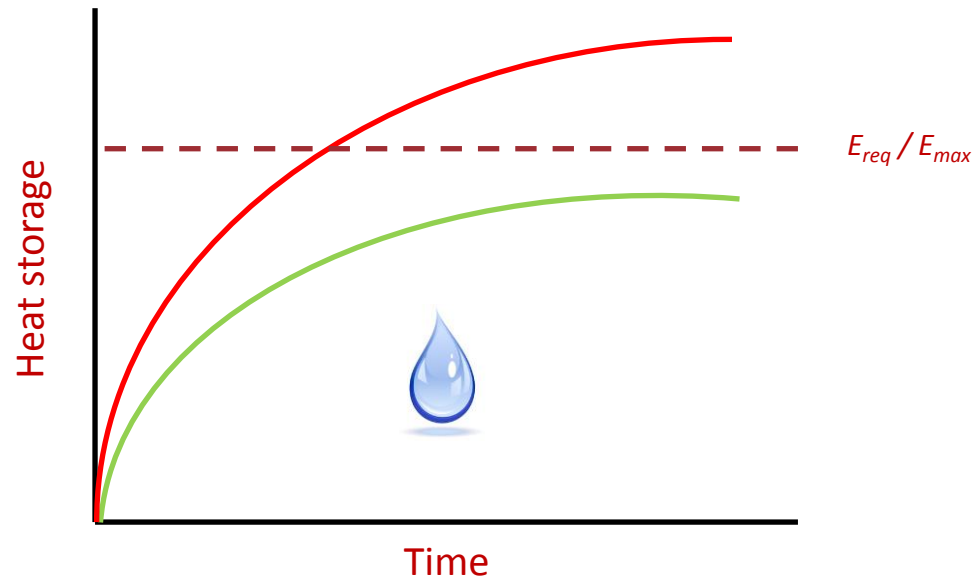
Thank you



Heat tolerance test – Biophysics



5 km/h, 2% grade
40°C and 40% RH
120 min



Body mass	E_{req} (W)	E_{max} (W)	ω	SR_{req} (L/h)
60 kg	485	823	0.59	0.87
90 kg	695	968	0.72	1.39

ω_{max}

1.0 = Maximum

0.70 = Untrained and un-acclimatised

0.85 = Trained

0.95 = Heat acclimatised

E_{req} : Requirement for evaporative cooling

E_{max} : Maximal evaporative capacity of the environment

ω : Skin wettedness