

## Running in Extreme Environments

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### Impact of skin and deep body temperatures

Skin temp (°C)	Consequence	Core temp (°C)	Consequence
42+	Burns	42-44	Death
33-41	Hot	40-44	Heat Stroke
28-33	Comfort	37.5-40	Hyperthermia, heat syncope, heat exhaustion
25-28	Cool discomfort	36.5-37.5	Normothermia
20	Impaired dexterity	36-33	Mild hypothermia
15	Pain	33-25	Moderate hypothermia
10	Numb	<25	Profound hypothermia and death
5	NFCI (with time)		
<-0.55	Frostbite		

Taylor, Mekjavic & Tipton (2003)



### TENGHESKHAN ICE MARATHON: PREPARATION STRATEGY AND THE EFFECT OF EXERCISE IN AN EXTREME COLD ENVIRONMENT IN A GROUP OF EXPERIENCED ULTRARUNNERS

2017

- Jan 2016, mountains of the Tereji National Park, Mongolia, Ta -35 °C
- Multinational group of experienced ultrarunners (n=9, male 5, 25-53 y)
- Concerns about safety in a remote environment were universal
- Consensus regarding clothing, equipment, hydration and nutrition
- The race was completed in 3:05-5:50. **No significant difficulties:**
  - Freezing around the nostrils and irritated the airways
  - No cold-induced bronchospasm
  - No cases of hypothermia
  - Two cases of frostbite; earlobe (moderate) and nose (mild)
  - No DOMs

### Risk factors for hypothermia

Cold air/water temperature	
Air/water movement	Faster moving fluids increase convective heat loss
Age	Children and small adults cool faster than large adults due to their lower levels of subcutaneous fat and higher surface area to mass ratio
Body stature	Tall thin individuals cool faster than short stocky people
Body morphology	Body fat and unperfused muscle are good insulators
Gender	Females tend to have more subcutaneous fat than men
Fitness	High fitness enables higher heat production Hypoglycaemia attenuates shivering. Injury and exhaustion reduce heat production – all three increase cooling
Nutrition/Fatigue/Injury	
Intoxication	Drug or alcohol depressant effects on metabolism
Lack of appropriate clothing	Insulation without wind proofing or vice versa

### Rewarming

**Mild hypothermia**

- Warm sweet drink and external heat applied to speed thermal comfort
- External active rewarming e.g. hot air or water-circulating blanket, hot packs, hot bath

**Severe hypothermia**

- Regard as critically ill, handle as fragile and as gently as possible
  - Risk of VF is increased in a cold myocardium and can be precipitated by movement, CPR, insertion of a supraglottic airway or tracheal intubation
- In cases of out-of-hospital moderate and severe hypothermia, passive rewarming is the safest way to rewarm (insulate and allow the casualty's metabolism to rewarm then slowly ~ 0.75 to 1.0 °C per hour)
- Extracorporeal life support (ECLS), including cardiopulmonary bypass and extracorporeal blood warming and oxygenation (ECMO), has revolutionised the management of hypothermic cardiac arrest.

(Nielsen et al. 1992; Handley et al. 1992)

### Cooling of Superficial Nerves and Muscles

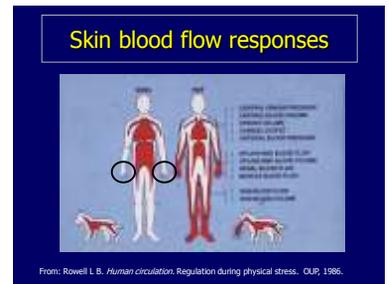
- Maximum power output falls by 3% per °C fall in muscle temperature
- Below T<sub>local</sub> of 20°C: rate of conduction and amplitude of action potentials is slowed
- Physical incapacitation at a T<sub>m</sub> of 27 °C

Clarke et al (1958); Vincent & Tipton (1988)

### Limitations to aerobic exercise performance and VO<sub>2max</sub> in the cold

- Lower T<sub>db</sub>, T<sub>m</sub> & T<sub>sk</sub>
- Increased lactate
- Lower glucose levels
- Increased VO<sub>2</sub>/reduced economy
- Reduced HR<sub>max</sub>
- Lower cardiac output

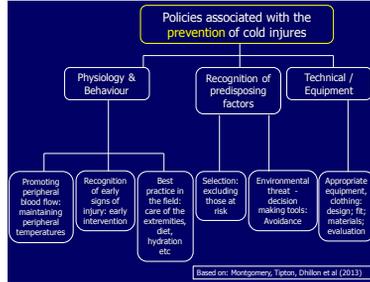
### Skin blood flow responses



From: Rowell L.B. Human circulation. Regulation during physical stress. OUP, 1986.

### Risk factors for cold injuries:

Physiological	Medical
Ethnicity (Afro-Caribbean descent)	Hypertension
Age	Atherosclerosis
Sex (Women)	Arteritis
Hypothermia	Raynaud's Disease
Prior MFI	Vasospastic disorders
Trauma	Anaemia
Erythrodermas	Sickle cell disease
Hyperhidrosis	Diabetes
Hypoxia	Shock
Smoking	Vasoconstrictors
Energy depletion	
Poor physical conditioning	

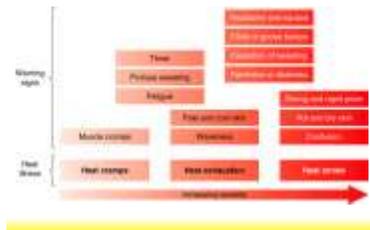


### Out of Hospital Treatment

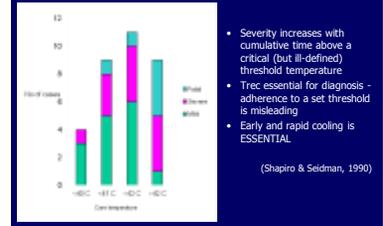
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|---|---|
| <h4>Frostbite</h4> <ul style="list-style-type: none"> <li>• Shelter</li> <li>• Frostnip – rewarm 10 min (ampit)</li> <li>• Superficial/deep frostbite: EVACUATE</li> <li>• Prevent further cooling</li> <li>• Rewarm <b>cautiously</b> <ul style="list-style-type: none"> <li>- Re-exposure unlikely</li> <li>- Further trauma unlikely</li> <li>- Follow-up treatment available</li> </ul> </li> <li>• Rewarming           <ul style="list-style-type: none"> <li>- Do not rub injured part</li> <li>- Whirlpool bath + antiseptic maintain at 38 °C for 15-30 min until red/purple colour and tissues pliable, expose to warm air</li> <li>- Topical aloe vera essential (anti-prostaglandin agent), loose protective dressing</li> <li>- Aspirin, Ibuprofen</li> </ul> </li> </ul> | <h4>NFCI</h4> <ul style="list-style-type: none"> <li>• Shelter</li> <li>• Carefully remove boots &amp; socks</li> <li>• Slightly elevate the limb</li> <li>• Rewarming           <ul style="list-style-type: none"> <li>- Insulate area <b>cautiously</b> rewarm rapidly</li> <li>- Slowly, by exposure to warm air alone (no immersion)</li> <li>- Encourage movement of toes &amp; ankles</li> <li>- Painful; Amtripyryline (10-75 mg in a single dose at night) - weak evidence base</li> </ul> </li> <li>• Severe cases (tissue damage) 2x daily cleansing with dilute antibacterial preparation</li> <li>• Photograph tissue damage</li> <li>• Prevent damage to skin</li> </ul> |
|---|---|

### Direct effect of heat

### WARNING SIGNS OF HEAT DISORDERS



### Severity of EHI related to the cumulative time above a critical body temperature



- Severity increases with cumulative time above a critical (but ill-defined) threshold temperature
- Trec essential for diagnosis - adherence to a set threshold is misleading
- Early and rapid cooling is ESSENTIAL

(Shapiro & Seidman, 1990)

### Individual susceptibility to Heat Illness

- Environmental conditions
- Body size (mass, skinfold thickness)
  - heat stroke occurs 3.5 times more frequently in excessively overweight young adults than in individuals of average body mass
- State of training / sudden increase in tempo
  - military recruits with low aerobic fitness (>12 mins for 1.5 mile run) and a high body mass index (>26) have a 9-fold greater risk of heat illness
- Degree of acclimatisation
- Hydration status
- Clothing worn
- State of Health: fever, viral illness, cold, GI disturbances
- Genetic profile: responsiveness to heat
- Genetic disorders: malignant hyperthermia
- Skin disorders - sunburn over 5% of body surface: impairs thermoregulation 21d
- Use of medication - diuretics, antihistamines
- Sweat gland dysfunction (e.g. prickly heat)
- Salt depletion
- Age

Tipton (2015)

- Competition changes the relationship between perceived and actual thermophysiological state
- It alters behavioural thermoregulation and increases thermophysiological strain - this could increase the risk of heat-illness
- Psychophysiological and psychological measures may identify susceptible individuals

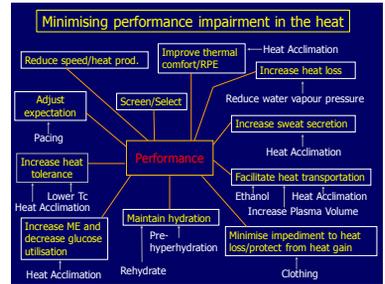
### Indirect effect of heat

### Performance Impairment with Heat Stress

Three primary mechanisms:

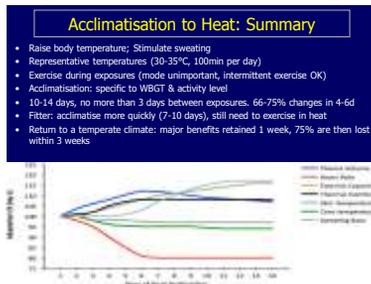
- Effects on cardiovascular function:** with increasing deep body & skin temperatures, increase in SBF & cutaneous venous volume compromises cardiac filling and SV. HR increases to preserve Q (e.g. Cheuxront et al, 2010)
- Effects on muscle function:** muscle hyperthermia leads to fatigue due to increased rates of muscle glycogen utilisation leading to substrate depletion + decreased oxidation rates of ingested CHO (e.g. Febbraio, 2000)
- Effects on the central nervous system (CNS):** above a 'critical' core temperature of ~40°C, there is reduced 'central command' to exercise - fatigue & increased RPE (e.g. Nybo & Nielsen, 2001)

### Heat: Mitigation



### Acclimatisation to Heat: Methods

- The exposures can be:
  - In the field (acclimatisation)
  - In a suitable climatic chamber (acclimation)
  - Using sweat suits (impermeable/semi-permeable clothing) or saunas - partially effective
  - Passive (e.g. hot bath) - partially effective
  - With exercise
    - Constant work
    - Self-paced work
    - Controlled hyperthermia



### HA Update – last 5 years

- Performance (TT,  $\dot{V}O_{2max}$ , power output, lactate, PV,  $Q_{skn}$ ) may be improved in cool conditions (13 °C) following HA, but this is unaffected by an additional hypoxic stressor (Lorenzo et al. 2010; Rendell et al. 2017)
- Short term heat acclimation (5 x 90 min, Tc 38.5) with permissive dehydration has been shown to effectively induce HA (PV, HR, Tc, Rowing performance) (Garrett et al. 2014)
- But, when thermal-strain is matched, permissive dehydration which induces a mild, transient, hypohydration does not affect the acquisition and decay of HA, or endurance performance parameters (Neal et al. 2016)
- A separate moderate overnight normobaric hypoxic-stimulus does not affect the time-course or magnitude of HA (Rendell et al. 2017)
- Individual variation: HA indices are mainly independent, 'low' or 'high' responders on one index do not necessarily demonstrate similar response across other indices (Corbett et al. 2015)

### Hand Cooling: Athens 2004, Beijing 2008, Rio 2016, Tokyo 2020

Sir Bradley Wiggins

Sir Chris Hoy

Thank you

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