Running in Extreme Environments

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### Risk factors for hypothermia

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Temperature</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactivity</td>
<td>&lt;25°C</td>
<td>Fatigue, depression, confusion</td>
</tr>
<tr>
<td>Age</td>
<td>Children, elderly, and adults cool faster than large adults due to lower mass : surface area ratio</td>
<td></td>
</tr>
<tr>
<td>Cold location</td>
<td>adults cool faster than large adults due to lower mass : surface area ratio</td>
<td></td>
</tr>
<tr>
<td>Body position</td>
<td>adults cool faster than large adults due to lower mass : surface area ratio</td>
<td></td>
</tr>
<tr>
<td>Body temperature</td>
<td>adults cool faster than large adults due to lower mass : surface area ratio</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Men cool faster than women due to lower levels of subcutaneous fat and higher surface area to mass ratio</td>
<td></td>
</tr>
<tr>
<td>Body morphology</td>
<td>adults cool faster than large adults due to lower mass : surface area ratio</td>
<td></td>
</tr>
</tbody>
</table>

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### Cooling of Superficial Nerves and Muscles

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

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### Limitations to aerobic exercise performance and VO\(_{2\max}\) in the cold

- Lower Tbd, Tm & Tsk
- Increased lactate
- Lower glucose levels
- Increased VO\(_{2\max}\), reduced economy
- Reduced HR\(_{max}\)
- Lower cardiac output

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### Skin blood flow responses

Risk factors for cold injuries:

<table>
<thead>
<tr>
<th>Physiological</th>
<th>Medical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothermia (also known as hypothermia)</td>
<td>Hypotension</td>
</tr>
<tr>
<td>Excess</td>
<td>Asthma</td>
</tr>
<tr>
<td>Use</td>
<td>Nephropathy</td>
</tr>
<tr>
<td>Hypofibrin</td>
<td>Rheumatoid arthritis</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Vasculitis disorders</td>
</tr>
<tr>
<td>Diabetic</td>
<td>Asthma</td>
</tr>
<tr>
<td>Smoking</td>
<td>Heart disease</td>
</tr>
<tr>
<td>Apnea</td>
<td>Diabetic</td>
</tr>
<tr>
<td>CVA</td>
<td>Atherosclerotic</td>
</tr>
<tr>
<td>Arthritis</td>
<td>Atherosclerotic</td>
</tr>
<tr>
<td>Fibromyalgia</td>
<td>Arthritis</td>
</tr>
<tr>
<td>Chronic conditions</td>
<td>Genetic profile</td>
</tr>
</tbody>
</table>

Policies associated with the prevention of cold injuries

- Hydration and nutrition
- Proper clothing and equipment
- Early recognition of symptoms
- Appropriate medical intervention

Direct effect of heat

WARNING SIGNS OF HEAT DISORDERS

- Extreme thirst
- Heavy sweating
- Weakness or fatigue
- Skin feeling cool
- Light-headedness

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

- Frostbite
- NFCI

Out of Hospital Treatment

Frostbite

- Shiver
- Hypothermia
- Use of medication
- Careful removal of shoes and clothes
- Rewarm rapidly
- Use of topical creams and gels
- Rewarm 10 min (armpit)
- Insulate area
- Prevent further cooling
- Photographic tissue damage
- Prevent damage to skin

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Individual susceptibility to Heat Illness

- Environmental conditions
  - Body size (mass, body length)
  - Body mass index (BMI)
  - Height
  - Degree of acclimatisation
  - Fitness level
  - Muscle mass

- Genetic and constitutional factors
  - Hyperthermia
  - Vitamin D deficiency
  - Hypothyroidism
  - Heart disease

- Psychosocial factors
  - Energy depletion
  - Stress
  - Sleep loss

- Age
  - Elderly
  - Infants

- Gender
  - Women
  - Men

- Ethnicity
  - African
  - Asian
  - Caucasian

- Environmental conditions
  - High temperature
  - High humidity

- Pre-existing conditions
  - Hypothyroidism
  - Hypertension
  - Diabetes

- Other factors
  - Drug use
  - Alcohol intake

- Psychological factors
  - Stress
  - Sleep loss

- Medications
  - Nonsteroidal anti-inflammatory drugs
  - Decongestants

Indirect effect of heat

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

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Performance Impairment with Heat Stress

Three primary mechanisms:

1. 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. Cheuvront et al, 2010).

2. 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).

3. 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).

Performance Impairment with Heat Stress

Heat: Mitigation

- Reduce water vapour pressure
- Increase sweat secretion
- Facilitate heat transportation
- Minimise impediment to heat loss/protect from heat gain
- Maintain hydration
- Increase heat tolerance
- Improve thermal comfort/RPE
- Reduce heat loss
- Reduce heat gain
- Increase plasma volume
- Prevent hypohydration
- Regulate heat production
- Minimise dehydration
- Prevent hypothermia
- Clothing

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

Acclimatisation to Heat: Summary

- Raise body temperatures; Stimulate sweating
- Representative temperatures (30-35°C, 100min per day)
- Exercise during exposures (inside uninvolved, intermittent exercise OK)
- Acclimation specific to 38°C, ~85% relative level
- 10-14 days, no more than 3 days between exposures: 66-75% changes in 4-6 days
- Other: accelerated non-athletic (~3-4 days), still need to exercise in heat
- Return to a temperate climate: major benefits retained 1 week, 75% are then lost within 3 weeks

HA Update – last 5 years

- Performance (TT, V2max, power output, lactate, PV, Qmax) may be improved in cool conditions (13°C) following HA, but this is suppressed by an additional hypoxic stimulus (Lorenzo et al. 2010; Rendell et al. 2017)
- Short term heat acclimation (5 x 90 min, Tc 38.5°C) 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 (Neal et al. 2016)
- 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. 2018)


Sir Chris Hoy

Sir Bradley Wiggins

Thank you

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