Exercise in the heat: what factors influence performance and health?

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- Has no relevant financial relationships to disclose
- Will not be discussing the off-label or investigational use of products
• Basics of thermoregulation
  • Heat production/dissipation
  • Heat illness

• Influence of heat stress on exercise performance
  • Endurance and team/individual sports
  • Exercising in Doha

• Pathways of fatigue in the heat
  • Mechanisms of fatigue (how and why)
  • Thermal and cardiovascular strain
  • Countermeasures
- Human body temperature ~37.0°C
- Hypothalamus integrates signals from skin and deep core thermosensors
- Exercise, fever, ambient conditions, medication
THERMOREGULATION – SET POINT

Skin blood vessels dilate: capillaries become flushed with warm blood; heat radiates from skin surface

Body temperature decreases: blood temperature declines and hypothalamus heat-loss center "shuts off"

Blood warmer than hypothalamic set point

Blood cooler than hypothalamic set point

Stimulus: Increased body temperature (e.g., when exercising or the climate is hot)

Stimulus: Decreased body temperature (e.g., due to cold environmental temperatures)

Homeostasis = normal body temperature (35.6°C–37.8°C)

Sweat glands activated: secrete perspiration, which is vaporized by body heat, helping to cool the body

Skeletal muscles activated when more heat must be generated; shivering begins

Activates heat-promoting center in hypothalamus

Imbalance

Body temperature increases: blood temperature rises and hypothalamus heat-promoting center "shuts off"

Skin blood vessels constrict: blood is diverted from skin capillaries and withdrawn to deeper tissues; minimizes overall heat loss from skin surface

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**Upper limit for survival**

- Impaired thermoregulation, heat stroke, brain damage

**Extreme physical exercise and fever**

- Resting core temperature 36.5°C – 37.5°C

**Intense shivering and impaired coordination**

- Violent shivering, speech and thought impaired

**Decreased shivering, erratic movements, incoherent**

- Muscular rigidity, semiconscious

**Unconscious, cardiac arrhythmias**
## EXERTIONAL HEAT ILLNESS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Symptoms</th>
<th>Management</th>
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<tbody>
<tr>
<td>Heat cramps</td>
<td>Brief, painful skeletal muscle spasms</td>
<td>Rest; replacement of electrolytes; avoid salt tablets</td>
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<tr>
<td>Heat exhaustion</td>
<td>Mild to moderate illness with inability to sustain cardiac output; moderate (&gt;38.5°C [101.3°F]) to high (&gt;40°C [104°F]) body temperature; often accompanied by dehydration</td>
<td>Move supine individual to cool, shaded environment, and elevate legs; loosen or remove clothing, and actively cool skin; administer oral fluids</td>
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<tr>
<td>Heatstroke</td>
<td>Profound CNS abnormalities (agitation, delirium, stupor, coma) with severe hyperthermia (&gt;40°C [104°F])</td>
<td>Ensure an open airway, and move to a cool environment. Immediately cool to &lt;39°C (102.2°F) using ice packs, water bath, wetting with water and continuous fanning; IV fluid administration; reestablish normal CNS function; avoid antipyretics or drugs with liver toxicity</td>
</tr>
</tbody>
</table>
Heat gain & loss

- Radiation
- Conduction
- Convection
- Evaporation

Radiation

Diffused radiation

Direct radiation

Wind

Conduction

Reflected radiation

Evaporation

Convection

Heat gain & loss

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• Responses: posture, clothing, seek shade, voluntary movement
• Basics of thermoregulation
  • Heat production/dissipation
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• Pathways of fatigue in the heat
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  • Thermal and cardiovascular strain
Impact of weather on marathon performance

*WBGT: wet-bulb-globe temperature index (temperature, humidity, solar radiation and wind)
Impact of heat on cycling performance

- **COOL**: 18°C - 40% RH
- **HOT**: 35°C - 60% RH

750 kJ cycling time trial

Impact of heat on cycling performance


43.4 km cycling time trial
COOL: 8°C - 30% RH
HOT: 36°C - 15% RH
Match-play tennis in the heat

Match characteristics
- Aces & double faults (%)
- Point duration
- Number of points
- Number of games
- Between point duration (~10 s)
- Effective playing (~3.5%)
PERFORMANCE IN THE HEAT

Football match in the heat (Doha)

Sprint speed

- 33.3 km.h\(^{-1}\)
- 32.1 km.h\(^{-1}\)

Number / Distance sprints

- ~ 12 sprints
- ~ 20 m

Total / High intensity running distance

- 10.3 km / 2.2 km
- 9.6 km / 1.7 km

Successful crosses & passes

- 74%
- 66%

Competitive match
Cool: 21°C
Hot: 43°C

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Mohr et al. (2012) PLoS One
Presentations Outline

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TEMPERATURE REGULATION AND PERFORMANCE

Cool

Hot

O₂ delivery

Heat dissipation
CARDIOVASCULAR STRAIN IN THE HEAT

- Exercising at the same absolute work load is relatively harder

Fick Equation:
\[ \text{VO}_{2\text{max}} = Q \times \text{a-vO}_{2\text{diff}} \]

\( Q \) = cardiac output
\( \text{a-vO}_{2\text{diff}} \) = arteriovenous oxygen difference

Rowell (1974) Physiol Rev
THERMAL AND CARDIOVASCULAR STRAIN

Périard et al. (2011) Exp Physiol
• Thermoregulatory-mediated rise in cardiovascular strain:
  - ↓ sustainable and maximal \( \text{VO}_2 \)
  - ↓ sustainable and maximal power output
  - ↑ relative exercise intensity
THERMAL AND CARDIOVASCULAR STRAIN

4 x 15 min Time Trials
COOL: 18°C - 40% RH
HOT: 35°C - 60% RH

Exercise is regulated by maintenance of relative intensity within narrow range

In response to sensory information stemming from a thermal strain-mediated increase in cardiovascular strain
THERMAL AND CARDIOVASCULAR STRAIN

↓ Exercise Work Rate

↑ Perceived Exertion

Thermal Perception
(↑ warmth discomfort)

Cardiovascular Strain
(↓ peak oxygen uptake)

↑ Ambient Temperature

↑ Skin Temperature

Core Temperature
COUNTERMEASURES – HEAT ACCLIMATION

Adaptation (% Day 1) vs. Days of heat acclimation

- Sweat rate
- Exercise capacity
- Thermal comfort
- Plasma volume
- Skin temperature
- Core temperature
- Heart rate

HYDRATION

- Hydrate before, during and after exercise
- Consume 6 ml per kg of body mass every 2-3 h to start exercise euhydrated
  - 6 x 70 = 420 ml
- Drink 150-200 ml every 15-20 min during exercise
  - Cold, low sugar drink with sodium (salty sweaters)
- Recovery hydration regimens should include sodium, carbohydrates and protein
COUNTERMEASURES – PREVENTING HEAT ILLNESS

• Optimise physical fitness before exercise in the heat
• Awareness of early symptoms of heat illness
• Avoid heavy exercise in the heat during:
  • Infection (fever)
  • Insufficient sleep
  • Glycogen depletion or hypoglycaemia
• Schedule sessions in cooler parts of day
  • Cancel or postpone exercising in extreme heat (>36ºC)
SUMMARY

• Basics of thermoregulation
  • Autonomic and behavioural thermoregulation
  • Understand and recognize heat illness

• Influence of heat stress on exercise performance
  • Decrease in endurance performance
  • Increase in brief/explosive tasks
  • Heat stress influences perception

• Pathways of fatigue in the heat
  • Thermal and cardiovascular strain interact
  • Increase in relative exercise intensity
  • Countermeasures
THANK YOU

- Aspire Zone Foundation
- QNRF – Junior Scientists Research Experience Program