Hypothermia!

The Terra Nova viewed from an iceberg near Scott’s camp

What is hypothermia?

- Clinically, a core temperature < 35°C
  - mild (shivering, numb hands, reduced dexterity)
  - moderate (violent shivering, reduced fine motor and mental function) 35 to 32 °C
  - profound (< 32°C) unconsciousness, ↓ HR and breathing, arrhythmias (<28°C), asystole (< 20°C)

Potential for hypothermia

- Extreme environments
  - Antarctic (-129°F, coldest recorded on Earth)
  - Arctic (-60°C in Siberia)
  - Altitude (↓ 1°C every 100 m, -40°C on Everest)
- Winter sports / military
- Water immersion
- Stranded motorists
- The elderly
  - minimum safe indoor temperature is 70°C

Ambient cold limits

- Depends on the duration and extent of exposure
  - nude, feels cold at < 25°C
  - manual dexterity, < 12°C
  - touch sensitivity, < 8°C
  - peripheral tissues freeze around -0.5°C
- wind effect, wind chill index
- water effect, 25x greater conductivity

Wind Chill Effect

Physiological Responses

- Skin blood flow (increase insulation)
  - ↓ with cooling until 10°C
  - < 10°C, hunting reaction
- Shivering
  - ↑ heat production 5 fold
  - unique to birds and mammals
- Voluntary exercise
  - ↑ heat production 15 fold
- Non-shivering thermogenesis
Non-Shivering Thermogenesis

- Babies
  - 4% body wt is brown fat (BAT)
  - rich in mitochondria
  - UCP, uncouples fuel metabolism and energy production, ↑ heat
  - stimulated by NE via β-adrenergic receptors

NST in Adults?

- NST acct for differences in cold tolerance in adults?
  - BAT in white fat?
  - Skeletal muscle NST?
  - BAT role in susceptibility to obesity?

Plants that generate heat

- *Arum Maculatum* (type of lily called jack in the pulpit)
  - produces heat and volatizes chemicals to produce a smell to attract flies to pollinate
  - heat as high as 45°C
- *Soldanella montana* (alpine snowbell)
  - generates enough heat to melt surrounding snow

Chronic Exposure

- Human responses to repeated cold exposure are “unimpressive” compared to other animals
  - little more than some habituation responses
  - for years it was debated whether humans could acclimatize to cold

Cold Habituation

- Fishermen who have cold hands all day have less skin vasoconstriction

Cold Acclimatization?

- Metabolic acclimatization
  - Increase BMR?
  - Shivering thermogenesis (3 METs)
  - Non-shivering thermogenesis
- Insulative acclimatization
  - Vasoconstriction

Victor Boyarsky
Acclimation patterns (3)

• Habituation (fishermen)
  – less vasoconstriction,
  – less shivering, less increase in BMR
  – greater fall in rectal temperature

• Metabolic pattern (Ama Divers)
  – increase BMR
  – increase shivering and NST

• Insulation pattern (Australian aborigines)
  – increased VC
  – increased subcutaneous fat

What determines the acclimation pattern?

Ama Women Divers

• Suk Ki Hong, a lifetime of studying Ama (Japan) and hae-hyo (Korea) women divers
• Extreme cold exposures before 1977
  – frequent dives, year round, in cold water
  – deep body cooling to 35°C
  – light cotton swim suits until 1977
• Wet suits after 1977
  – longer dives but no longer deep body cooling

Ama Cold Acclimatization?

• Metabolic acclimatization,
  – 30% increase BMR in winter
  – increased utilization of thyroid hormone by peripheral tissues

• Insulative acclimatization
  – Increased non-fatty insulation shell
    • greater VC, better countercurrent effect, thicker muscle insulation

• Habituation acclimatization
  – lower core temperature threshold for shivering

Cold Injuries

• Chilblains
  – red, itchy patches of skin (fine capillary damage)

• pernio
  – superficial burning and pain

• Trench foot, immersion foot
  – prolonged immersion of feet in cold water
  – prolonged VC causes ischemic damage to tissues

• frost nip (surface layers), Frost bite (deeper layers),
  – freezing of the tissues

Frostbite
Unexpected effects of cold

- Increases MI, stroke, respiratory disease deaths
  - vasoconstriction
  - dehydration
  - increased blood clotting
  - longer survival of bacteria
  - closed environments
  - inhibits innate immunity

Scott vs Admundsen Story

- Roald Admundsen
  - superb skiers
  - well provisioned
  - dogsledgers

- Robert Falcon Scott
  - military discipline
  - austere provisioning
  - ponies and sledges

Scott 78 days
Admundsen 57 days

Scott' diary

- Expedition’s misfortune was not due to poor planning but to bad weather and bad luck.
  - “It was no one’s fault... every detail of our food supplies, clothing and depots... worked out to perfection... We missed getting through by a narrow margin which was justifiably within the risk of such a journey”.

- Scott and his remaining 2 companions died within a days walk of their next depot of food.

- Scott allowed for 4500 kcal/d/man
- Pulling sledges requires > 7000 kcal/d/man

Hypothermic emergency treatment

- 29 yr-old Norwegian woman survived accidental hypothermia and revived from a Tc of 13.7 °C
  - fell in waterfall while skiing
  - survival more likely when rapidly cooled

- immerse in warm bath
- warm air to breathe
- blood warmed with heat exchanger
- be ready for arrhythmias
Acute effects of Cold

- ↑ muscle blood flow
- ↑ cardiac output only by ↑SV
  - no ↑HR because of vc?
- ↑urine, ↓PV
- ↑EPI and NE which ↑FFA and glucose
- ↑cortisol which ↑blood glucose
- ↑thyroid hormone which ↑met rate
- carbohydrates become the preferred fuel?

BMR and Ta

Effect of cold on aerobic exercise endurance

- Increased metabolic cost
- lower body temperatures
- decreased cv endurance
  - ↓HR max, ↓Qmax, ↓VO2max
  - less O2 delivery to muscle (Hb/O2 binding)
- ↓ active muscle blood flow

Effect of cold on muscle function

- ↓ muscular endurance @ muscle temp < 27oC
  - reduced nerve conduction vel., ↓muscle fiber recruitment
- ↓ muscle strength and ↓ peak muscle power
  - slower force development
  - greater viscosity of sarcoplasm
  - slower chemical reactions

Factors that influence cold responses

- Age (children and elderly)
- Gender (females do better)
- Fitness (an advantage)
- Body fat (a big advantage)
- Alcohol (lowers blood sugar, dehydration, ↓ vd, ↓ shivering)

Other Approaches to Cold

- Countercurrent heat exchangers
  - bird legs, seal flippers, whales tails
- Specialized tissues
  - Antifreeze blood (glycoproteins), modified lipid membranes
- Estivation- body cooling and Suspended animation?
  - body under unfavorable environmental conditions
- Hibernation
  - Metabolism 1% above BMR
Behavior Cold Protections

- Increase metabolism
  - stamp feet
  - jump
- Increase insulation
  - clothing
- Huddling
  - birds
  - bees

Clothing

- Clo
  - measure of clothing insulation
  - 1 clo = insulative value of a regular business suit
  - insulation nec to maintain comfort of a seated adult in a 21°C room, 50%rh, 6 m/min air flow
- COLD
  - clean, open, layers, dry

Death in Cold Water

- Titanic, cause of death for most of the 1000 people not in lifeboats was hypothermia, not drowning
- Reflex gasp
- Hyperventilation (muscle tetany)
- Cardiac arrhythmias
- Post-rescue collapse

Afterdrop

To swim or not to swim?

- Swimming increases metabolic rate but also increases convective heat loss
- <15-20°C, ↓ Tc w/swim
- 16-24°C, depends on %fat
- 25-28°C, no effect of swimming on Tc
- >28°C, Tc increases with swimming