



Objectives

- Understand risk factors for heat illness and prevention of heat illness

Disclosures

- I have none

1st Law of Thermodynamics

- Energy can be neither created nor destroyed

Objectives

- Understand that working muscles generate heat which must be regulated
- Understand the mechanisms of heat transfer
- Be able to identify and manage:
 - Heat edema
 - Heat cramps
 - Heat syncope
 - Heat exhaustion
 - Heat stroke

Heat Production

- Comes from muscle work
- Muscles are inefficient
 - 15-30% of energy consumed is used for work
 - 70-85% is released as heat
- Heat is also produced during recovery
 - Restoration of homeostasis
- Resting heat production
 - 1.3 kJ per minute for a 70 kg man

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Heat Regulation

- Without regulation heat generated at rest would increase body temperature 1°C every 5 minutes
- Heat is sensed by thermodetectors in the hypothalamus
- Signals by the sympathetic nervous system initiate sweating and peripheral vasodilation

Evaporative

- Cooling is directly related to:
 - Sweat rate
 - Skin surface area
 - Airflow
- Cooling is indirectly related to:
 - Humidity
 - Clothing and protective equipment

Heat Transfer

- Evaporative – dissipates most heat when $> 68^{\circ}\text{F}$
- Nonevaporative – dissipates most heat when $< 68^{\circ}\text{F}$
 - Conduction
 - Convection
 - Radiation

Nonevaporative

- Conduction – heat transfer by direct contact
 - Dependent on temp difference, thermal conductivity, and transfer area
- Convection – heat transfer as a result of forced fluid flow
 - Dependent on temp difference and heat transfer coefficient (water 100 times greater than air)
- Radiation – heat transfer by electromagnetic waves
 - Can cause heat gain if temp greater than 95°F

Evaporative

- Occurs with change from liquid to gas
- Heat is transferred by evaporation of sweat and respiratory moisture
- Sweating begins at body temperature greater than 98.6°F
- Sweat rates vary from 600-3500 ml/hr
- Accounts for 98% of heat loss in hot, dry conditions

Equilibrium

- Acclimatized athletes maintain exercising temps between 98° and 104°F
- Failure of equilibrium results in a rise in core temperature

Heat Edema

- Edema involving the hands and feet
- Results from vasodilation combined with gravitational and centripetal forces causing pooling
- Unacclimatized individuals predisposed
- Improves with rest and elevation
- Resolves with acclimatization

Heat Syncope

- Syncope or lightheadedness often seen at the end of an endurance event
- Poorly acclimatized individuals and the elderly at highest risk
- Results from vasodilation and pooling of blood in the large muscles. Sudden cessation of exercise results in decreased heart rate and a cardiac output resulting in poor blood flow to the brain.

Heat Cramps

- Involuntary contractions of exercising muscle often in the heat
- Large lower extremity muscles are most common, but may occur anywhere
- Unknown cause
- Fluids loss, sodium loss, and neuromuscular fatigue have been proposed

Heat Syncope

- Prevention:
 - Acclimatization if possible
 - Proper hydration
 - Encouraging proper cool down

Heat Cramps

- Treatment involves:
 - Rest and cooling down
 - Stretching
 - Massage
 - Oral hydration
 - Salty foods (based on anecdotal evidence)
 - IV hydration if no improvement
 - IV diazepam if severe
 - May return to activities same day

Heat Syncope

- Treatment:
 - Lie down and elevate legs
 - Assess ABCs
 - Obtain vitals
 - Oral hydration
 - Assessment for other causes of syncope (MI, CVA, TIA)
- Usually resolves in less than 30 minutes
- No same day return to activities

Heat Exhaustion

- Inability to continue exercise
- Combination of heat stress and dehydration
- Inadequate cardiac response to heat stress
- Blood is shunted to the muscles and skin
 - Results in insufficient preload to maintain cardiac output

Heat Exhaustion

- Treatment
 - Move to a cool environment
 - Assess ABCs
 - Obtain vitals
 - Oral rehydration if tolerated
 - Obtain sodium level if starting IV fluids
 - Usually resolves in less than 2 hours
 - No same day return to activities

Heat Exhaustion

- Symptoms
 - Lightheaded
 - Fatigue
 - Chills
 - Headache
 - Nausea/vomiting

Heat Stroke

- Medical emergency
- Thermoregulatory failure
- May lead to:
 - Rhabdomyolysis
 - Renal failure
 - Disseminated intravascular coagulation
 - Pulmonary edema
 - Seizures
 - Shock/coma

Heat Exhaustion

- Exam
 - Profuse sweating
 - Cutaneous flushing
 - Irritability
 - Orthostatic hypotension
 - Uncoordination
 - Mild confusion
 - Elevated rectal temperature (usually below 104° F)

Heat Stroke

- Symptoms
 - Lightheaded
 - Fatigue
 - Chills
 - Headache
 - Nausea/vomiting

Heat Stroke

- Exam
 - Anhydrosis
 - Cutaneous flushing
 - Pronounced mental status changes (irritability, confusion, hysteria, psychotic behavior)
 - Hypotension
 - Rectal temperature > 104° F

Risk Factors

- Dehydration
- High BMI
- Poorly acclimatized, poorly conditioned, inexperienced
- Children
 - Produce more metabolic heat, sweat less
- Elderly
 - Less efficient at cooling, reduced vasodilation, decreased cardiac output

Heat Stroke

- Treatment
 - Remove from hot environment
 - Assess ABCs
 - Obtain vitals including rectal temp
 - Check sodium and glucose and consider other causes of altered mental status
 - Rapid cooling with cold water immersion, ice bath, or ice packs (neck, axilla, groin)
 - Monitor core temp and vitals (stop cooling at 102° F)

Risk Factors

- History of previous heat injury
- Acute illness
 - Fever can be additive to exercise heat
 - GI illness can lead to dehydration
- Chronic medical conditions
 - Sickle cell trait
 - Cystic fibrosis
 - Diabetes

Heat Stroke

- Treatment
 - Evaluate for signs of DIC (epistaxis, bleeding from IV sites, bruising)
 - Evaluate for signs of pulmonary edema (wet lung sounds)
 - Evaluate for signs of acute renal failure (peripheral edema)
 - Transfer to medical facility for signs of end organ damage
 - Return to activities 2 weeks following recovery

Risk Factors

- Medications
 - Amphetamines/stimulants – increased metabolic heat
 - Diuretics – dehydration
 - Ethanol - dehydration
 - Anticholinergics – decreased sweat production
 - Antihistamines – decreased sweat production
 - Antidepressants – decreased sweat production
 - Antipsychotics – decreased sweat production

Prevention

- Identifying risk factors
 - Pre-participation exam
- Avoid dehydration
- Allow 10-14 days for acclimatization if possible
- Monitor environmental conditions (WBGT)
 - Highest risk when greater than 82° F (28° C)
 - Adjust workout schedule and clothing based on conditions

Thank You!

- *Armstrong LR et al. Exertional heat illness during training and competition. Medicine and Science in Sports and Exercise.*
- *McKeag DB, Moeller JL. ACSM's Primary Care Sports Medicine 2nd ed. Philadelphia 2007.*
- *Madden CC et al. Netter's Sports Medicine. Saunders Elsevier. Philadelphia, 2010*
- *Marine Corps Marathon Hyperthermia Algorithm*

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