

Health impacts of heat stress



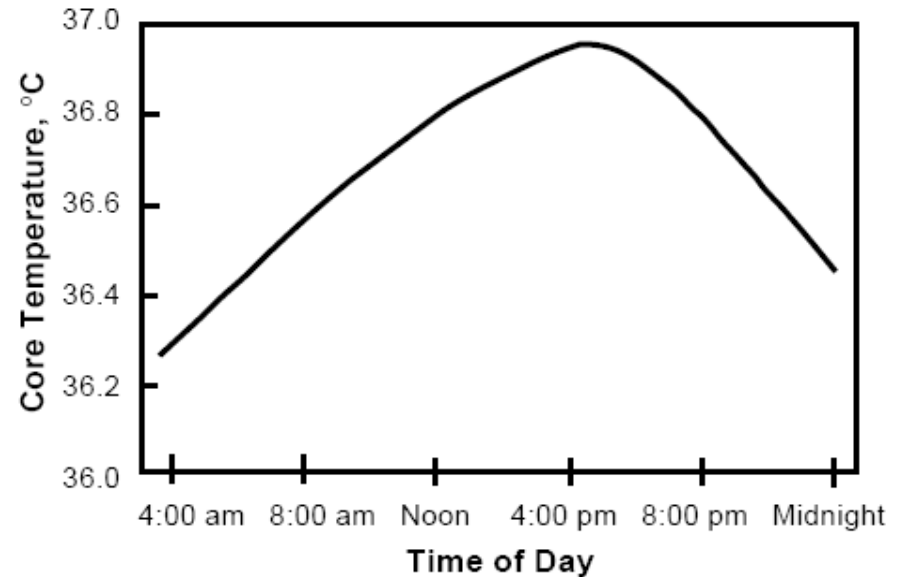
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Bodily thermoregulation

- Hypothalamus regulates body temperature within a narrow range for optimum functioning
 - Heat production
 - Muscle activity, food assimilation, and metabolism
 - Heat loss
 - Radiation, conduction, convection, evaporation, faecal and urine losses

Influences on bodily temperature

- Diurnal variation
- Menstrual cycle
- Basal metabolic rate, under endocrine influence
- Exercise may increase core temp to 40°C
- Ambient temperature



Exercise



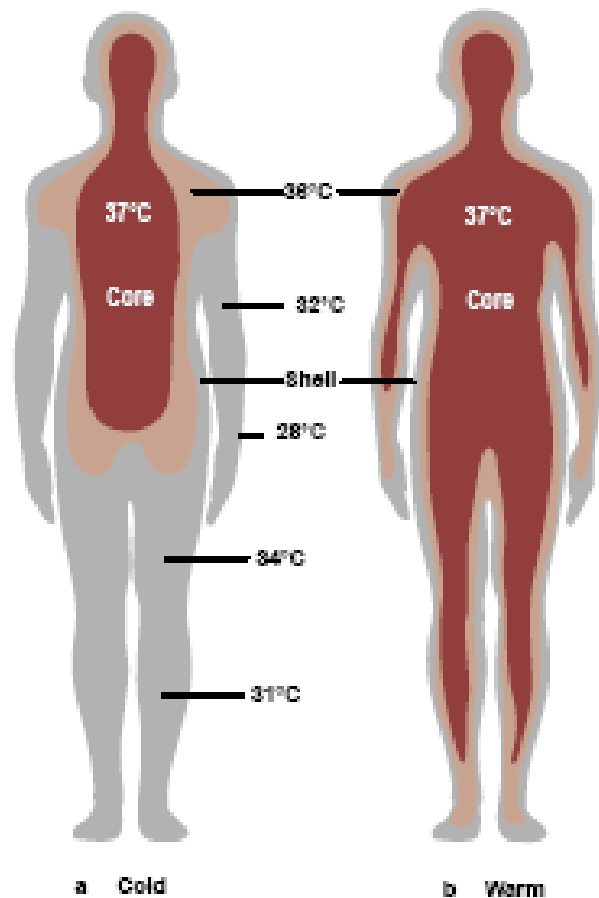
- Can increase heat production 10-fold
- Creates competing demands on circulation
 - Blood flow to muscle is several times greater than blood flow to skin
- Loss of fluids & electrolytes due to sweating

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Mechanisms of heat gain & loss

- Radiation
 - Heat transfer between objects not in contact
- Conduction
 - Heat transfer between the surfaces of objects in contact
- Convection
 - Heat transfer via the movement of a gas (air) or a liquid
- Dependent on the thermal gradient, the difference between ambient and body temperature. Therefore, two-way

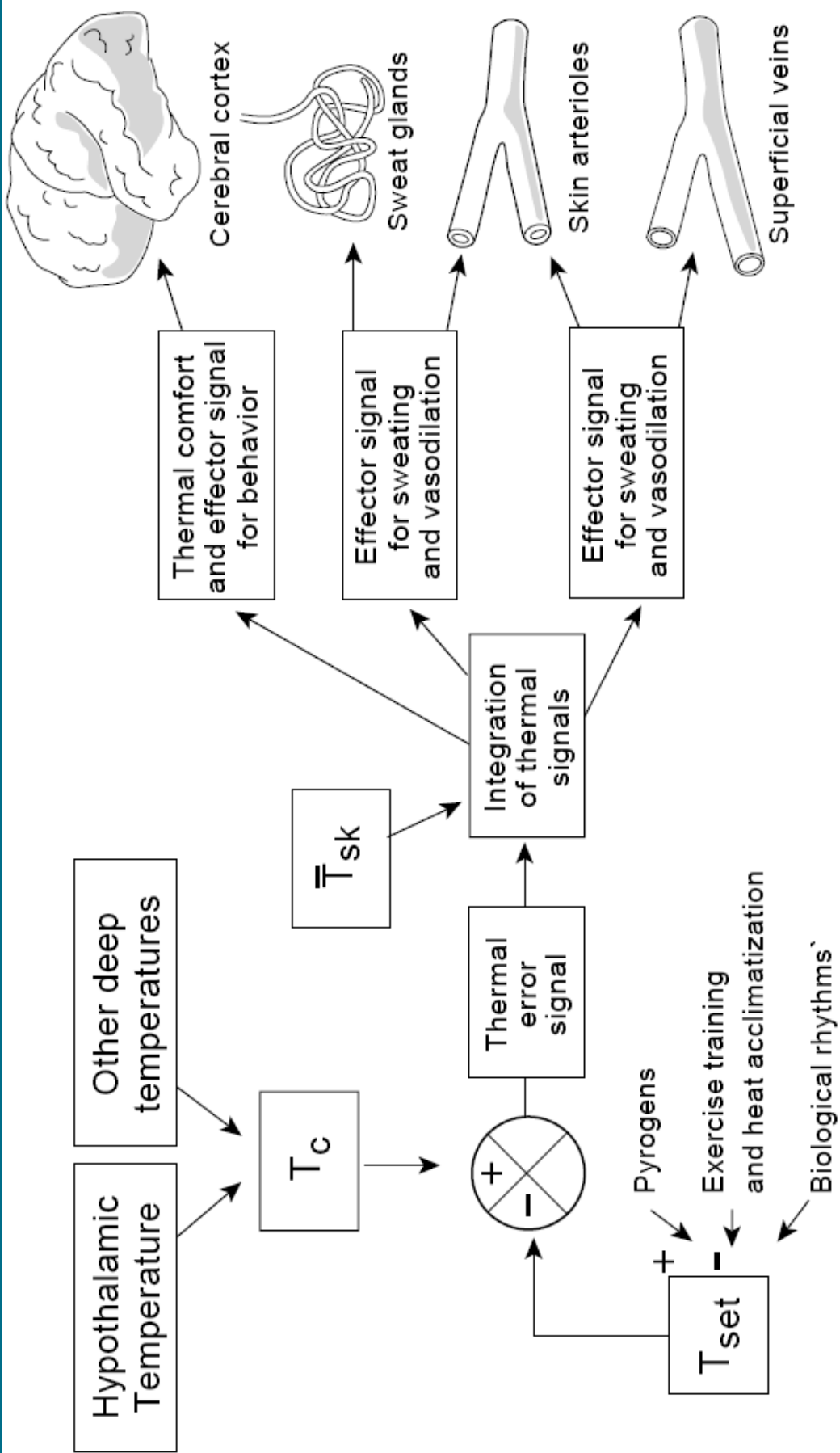
More on conduction



- The temperature of the skin determines body heat loss or gain
 - Skin temperature is varied by changes to skin blood flow
- Rate of blood flow through the cutaneous venous plexus varies from almost 0 to 30% of cardiac output

Mechanisms of heat loss

- When the ambient temperature is greater than skin temperature, *the only means by which the body can lose heat is by evaporation*
- Evaporation
 - From sweat, respiration, urine & faeces
 - Vaporisation of 1g of water removes 0.6kcal of heat
 - Insensible losses of 50mL/h
 - Maximal sweat losses of 1600mL/h if unacclimatised



- At 21°C ambient temperature, heat losses are due to:
 - Radiation & conduction 70%
 - Vaporisation of sweat 27%
 - Respiration 2%
 - Urine & faeces 1%
- At higher ambient temperatures, radiation declines and vaporisation increases

Reflex responses activated by a hot environment

- Increased heat loss
 - Cutaneous vasodilation
 - Sweating
 - Increased respiration
- Reduced heat production
 - Anorexia
 - Apathy and inertia

Insulation

- Fat conducts heat one-third as readily as other tissue types
- Heat is conducted from the skin to the air trapped against the skin by clothing, then to the inner and finally outer aspects of the clothes to the exterior
 - The rate of heat exchange through clothing is dependent on thickness & texture of fabrics

Wind and water

- The rate of heat loss by convection and evaporation is increased in the presence of wind, which replaces the air adjacent to the skin
- Water is a much greater conductor of heat than air

Sweat

- Controlled by sympathetic nervous system
- Sodium content varies from 5mEq/L at low rates of excretion to 60mEq/L at high rates of excretion
- Potassium, urea & lactic acid are also lost in sweat

Acclimatisation

- When exposed to 2 hours exercise per day in hot weather for 1 to 6 weeks:
 - The rate of sweating increases from 700mL/h to 1600mL/h
 - Sodium content of sweat decreases from 30g/day to 3-5g/day
 - Conservation of urinary sodium leads to expanded intravascular volume
- High aerobic fitness increases rate of acclimatisation
- The benefits of acclimatisation are

Effect of dehydration

- Exercise in warm-hot environment leads to dehydration of 2 - 6%, often with inadequate intake to compensate
- Thirst is not sensed until $> 2\%$ dehydration. Ad libitum water replacement is not adequate to replace losses
- $> 2\%$ dehydration leads to impaired cognition, increased risk of injury and increased susceptibility to heat stress illness

Consequences of dehydration

- Intravascular volume depletion
- Reduced venous return
- Reduced cardiac output / lowered BP
- Elevated heart rate
- Increased blood viscosity
- Aldosterone action on kidneys to retain sodium and water by concentrating urine
- Reduced volume available for sweat production
- Reduced tissue perfusion
- Reduced capacity for change in heart rate – age related, CVD, medication
- Increased clotting tendency
- Risk of kidney stones increased

Heat related illness

- Even with maximal sweating, the body's capacity to lose heat may be overcome, causing a rise in core temperature
- Excessive heating of the hypothalamus depresses its ability to regulate body heat and sweating diminishes
- A suite of over-lapping conditions
 - Heat cramps, heat exhaustion, heat stroke

Heat cramps

- Associated with strenuous activity
 - Inadequate sodium replacement and increased losses, leads to low serum sodium. This interferes with calcium-dependent muscle relaxation
 - Hyperventilation due to accumulated lactic acid produces a respiratory alkalosis and may contribute to tetany and cramps
 - Treat with rest and electrolyte replacement
- Muscular pain due to rhabdomyolysis

Heat exhaustion

- Dehydration and electrolyte loss due to sweating and inadequate replacement leading to hypovolemia and reduced tissue perfusion
 - Fatigue, light-headedness, nausea, vomiting, severe headache, elevated heart and respiratory rate, lowered blood pressure
 - Body temperature is normal or slightly elevated
 - Likely profuse sweating
 - Treat with fluid and electrolyte replacement

Heat stroke

- A medical emergency with a high mortality rate (up to 80%)
- Elevated temperature and associated neurological symptoms
 - Sudden loss of consciousness without warning
 - Irritability, combativeness, bizarre behaviour, hallucinations
 - Virtually any neurological abnormality: coma, convulsions, pupillary and reflex abnormalities, hemiplegia, decerebrate/decorticate posture
 - Difficult to distinguish from cerebrovascular accident unless diagnosis of heat stroke considered
- Absence of sweating is classic, but profuse sweating may be seen in early heat stroke. Skin may be pink or ashen
- Widespread organ injury, especially with core temp $>42^{\circ}\text{C}$

Heat stroke & organ injury

- Heart failure, hypotension and falling cardiac output suggest poor prognosis
- Hepatic injury
- Renal failure may occur secondary to decreased renal blood flow or rhabdomyolysis
- Bleeding disorders follow injury to vascular endothelium, platelet and clotting factor changes
- Dehydration may not be seen

Heat stroke treatment

- When diagnosis is suspected, rapid, aggressive therapy to lower body temperature
 - Remove patient from the source of heat
 - Remove clothing
 - Promote evaporative cooling by sponging entire skin surface and fanning
 - Ice packs to groins and axillae
 - Control shivering during cooling with diazepam
- O_2 support ventilation IV access (or

Predisposing factors for heat stress illness

- Extremes of age
- “Invulnerability of youth”
- Dehydration
- Lack of acclimatisation
- Lack of aerobic fitness
- Impaired ability to sweat
 - Congenital, cystic fibrosis, quadriplegia, scleroderma, anti-cholinergic medications, dehydration, age, skin disorders (incl. sunburn & prickly heat)
 - Impaired cardiac output – reduced capacity to tolerate shunting of blood to skin, and lowered intravascular volume
- Obesity
- Infection
- Alcoholism
- Mental illness
- Drugs impairing heat response
- Immobility

Heat associated illness

- Impaired cognition
- Kidney stones
- Impaired cardiac output
- Asthma / COPD secondary to pollution associated with heatwave weather events
- Falls
- Gastroenteritis

Heatwave mortality

- The threshold temperature for heat-related mortality is related to local summer temperature
 - The temperature at which mortality increases with increasing temperature is higher in warmer climates. The slope of the temperature-mortality curve is not predicted by latitude

Heatwave mortality

- Heat stroke seldom appears as cause of death even in studies of large numbers of heat-related deaths
- Rates of death increase in the following disease categories:
 - Cardiovascular disease, asthma/COPD, renal disease, diabetes, neurological disease, and cancer

Public health messages

- Target population
 - Elderly, especially with pre-existing illness, socially isolated, mobility impairment, their carers & community
 - Outdoor workers, sportsmen & women
 - Defined illnesses
 - CVD, respiratory disease, neurological disease, metabolic disease, renal disease, cancer
 - CF, schleroderma, quadriplegia, congenital impairment of sweating

Public health messages

- Preparedness
 - Aerobic fitness
 - Lose weight
 - Optimise chronic medical conditions
 - Acclimatisation to hot weather
 - Adequate home insulation & ventilation

Public health messages

- Prevention of heat-related illness
 - Adequate hydration. Avoid alcohol
 - Adequate nutrition will maintain sodium levels
 - Loose, light clothing
 - Avoid sunburn, prickly heat
 - Avoid unnecessary exercise
 - Shelter in cool, well-ventilated places
 - Relieve heat by bathing / sponging