The Limits of Human Endurance

Definition: The ability to sustain a stressful effort or activity for a long period of time

What qualifies as "long" varies with the intensity of the task (from minutes to hours, or even days)

ATP: Powering Muscle Contraction

- ATP is the immediate source of energy for muscle contraction, but is in limited supply

During muscle contraction, one of the phosphate groups breaks off, liberating energy

There are three energy systems that resynthesize ATP, to allow muscle activity to continue

Energy Systems

- ATP-PC (creatine kinase reaction)
  - provides immediate resynthesis of ATP via the breakdown of phosphocreatine stored in muscle
  - produces ATP very rapidly and efficiently
  - however, phosphocreatine stores last only ~10 seconds

- Anaerobic glycolysis
  - resynthesizes ATP by metabolizing carbohydrate without the involvement of oxygen
  - by-product is lactic acid, which leads to fatigue
  - can produce ATP at moderate-high rates for only a few minutes
Energy Systems

- Oxydative phosphorylation
  - resynthesizes ATP by metabolizing carbohydrates and fats in processes involving oxygen (i.e., aerobic)
  - by-products are water and carbon dioxide
  - can produce ATP at low-moderate rates for hours

Cardiopulmonary Function

- The cardiovascular and respiratory systems play a major role in endurance performance
- Together, these systems
  - obtain O₂ from the environment
  - deliver O₂ and fuel to the muscles
  - remove CO₂ and by-products from muscles
  - return CO₂ to the environment
  - also plays major role in heat dissipation

VO₂ max and Anaerobic Threshold

- VO₂ max – maximal oxygen consumption
  - Single best marker of cardiopulmonary fitness
  - Reflects maximal ability to transport and use O₂
  - Highly correlated with endurance capacity
  - Untrained: 40 ml/kg/min; Endurance athlete: 70+ ml/kg/min

- Anaerobic (lactate) threshold
  - The intensity at which lactate starts to accumulate in the blood stream (50-80% of VO₂ max)
  - Can be increased much more with training than VO₂ max

Fatigue

- Fatigue is the inability to maintain the desired speed, intensity, power, etc
- Failure to produce adequate ATP is a major source of fatigue (but not the only one)
- Why do you ultimately fail during a maximal aerobic bout of exercise:
  - Does the cardiopulmonary system not deliver enough O₂ (central limitation)?
  - or
  - Are the muscles unable to make use of the O₂ that is available (peripheral limitation)?
Environmental Factors

Two examples

- Train high – compete low?
  - Training at altitude leads to an increase in red blood cells
  - This improves endurance performance at altitude, but there is little benefit when returning to sea level

- Exercise in the heat
  - In the heat, more blood goes to the skin, meaning there is less to go to the muscles – this hurts performance
  - A major adaptation to the heat is increased sweating, which is effective as long as fluids are replaced

Ergogenic Aids

Two examples

- Blood doping
  - An athlete’s own blood is removed, and then re-infused several weeks later, right before competition
  - If timed properly, can improve endurance performance
  - Very hard, but not impossible, to detect

- Caffeine
  - Leads to greater use of fats during exercise, which spares carbohydrate stores; may also help with calcium availability in muscle
  - High levels in blood are prohibited, but low levels are not

Up next ...

- Factors that determine and limit human muscular power
- Muscles, genes, and athletic performance article