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The Limits of Human Endurance



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The Limits of Human Performance
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Kinesiology

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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)

intensity - endurance relation

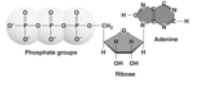
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ATP: Powering Muscle Contraction

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

adenosine triphosphate molecule



- 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

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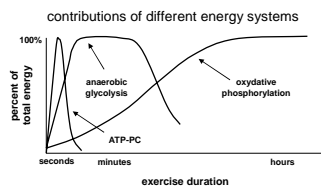
Energy Systems

- 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

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Energy Systems

- Oxidative 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 O_2 from the environment
 - deliver O_2 and fuel to the muscles
 - remove CO_2 and by-products from muscles
 - return CO_2 to the environment
 - also plays major role in heat dissipation

VO_2 max and Anaerobic Threshold

- VO_2 max – maximal oxygen consumption
 - Single best marker of cardiopulmonary fitness
 - Reflects maximal ability to transport and use O_2
 - 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 VO_2 max)
 - Can be increased much more with training than VO_2 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 O_2 (central limitation)?
 - or
 - Are the muscles unable to make use of the O_2 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