Exercise Induced Collapse: "Hitting the Wall"

Background
1. "Hitting the Wall" / "Bonking"
   - Severe energy loss during prolonged exercise
   - Runners collapse around 20 mile point in marathon
   - Possibly due to depletion of muscle glycogen
     - Fat stores (even in leanest runners) are inexhaustible
     - Unable to utilize fat without carbohydrate as primer for metabolism

Pathophysiology
1. Old theory: exhaustion of carbohydrate fuel
   - Muscle glycogen or blood glucose falls to critically low level
   - Glycogen depletion contributes to muscle fatigue
     - At 80 % maximum capacity
   - Glycogen content of muscles dropped near zero in 90 min
     - Marathon at normal pace
   - Fuel consumption ratio:
     - 75 % carbohydrates
     - 25% fatty acids
   - Carbohydrate supplies fall
     - Body relies on fatty acids
   - Body stores 2,000 calories of glycogen in muscles and liver
     - Enough for about 20 miles
2. New theory: CNS fatigue
   - Muscle damage may cause "hitting the wall"
   - Protective mechanism
     - Mediated by interleukin-6
       - Brain decreases muscle stimulation
       - Discomfort/exhaustion when muscle damage approaches dangerous levels during prolonged exercise
     - Mediated by serotonin
       - Prolonged exercise increases serotonin production
       - Tryptophan-amino acid
         - Precursor to serotonin
         - Increase levels with muscle damage
         - Increased tryptophan
           - Leads to increased serotonin
         - Increased serotonin causes brain to stimulate release of serum fatty acid
         - Increased serum fatty acid causes increased CNS fatigue
     - Mediated by insulin
       - Protein stimulates insulin release
       - Insulin speeds muscle cells' absorption of blood glucose by 50%
       - Transports amino acids into muscle
       - Decreased release of stress hormone cortisol
       - Stimulates blood flow to muscle
Diagnostics
1. Detailed history of syncopeal event
   - Time frame of collapse
     - Around 20 miles
2. Serum blood sugar for hypoglycemia
3. Serum Interleukin-6 level for muscle tissue damage
   - Experimental only
   - Possible correlation with exercise intensity
   - Does not correlate with length of exercise
4. Serum serotonin/tryptophan level
   - Experimental only
5. Insulin level

Therapeutics
1. CHO supplementation during exercise studies
   - 1960s-subjects exercised to exhaustion
     - Consumed 200 g of glucose
     - Extended performance by one hour
   - 3 fluids: 4:1 CHO-protein solution, normal sports drink, water,
     - CHO-protein beverage: 30 min
     - Carbohydrate-only group: 20 min
     - Water only group: 14 minutes
   - Endurox R4/Accelerade
     - Use a 4:1 carbohydrate-protein ratio
     - Enough protein to stimulate insulin secretion
     - Not enough to stimulate peptide enzymes and induce gastric distress

Training/Prevention
1. "Hitting the Wall" - multifactorial
2. Prevention needs to address diet and training:
3. Carbohydrate loading pre-event
   - 7 day pre-event cycle
     - Low CHO diet first three days to deplete glycogen stores
     - 70% CHO diet final four days
     - OR 75% CHO diet 7 days
       - Taper intensity of training 7 days prior to event
   - Both methods increased muscle glycogen up to 150%
4. Physiologic goal of training: optimize aerobic metabolism
   - Muscles increase utilization of oxygen
     - Due to increased size/number of mitochondria
     - Increased aerobic enzymes
   - Trained muscles better mobilize and use fat for energy
     - Preserves carbohydrate stores
   - Some muscle fibers can be adapted for aerobic or anaerobic exercise
     - For marathon, can adapt convertible muscles for aerobic/endurance work
   - Training increases:
- Number of capillaries
- Muscle nutrient supply
- Adaptation of cardiovascular/respiratory systems
  - Heart muscle: increased size, weight, blood volume
  - Resting and submaximal exercise heart rates decreased
  - Stroke volume-increases distribution of blood/oxygen to active muscles
- Maximal oxygen uptake (VO2 Max)
  - Quantitative measure of capacity for aerobic energy transfer (ability to do work)
- Variables that determine VO2 Max:
  - Heredity
  - Sex
  - Body composition (amount of lean body tissue)
  - Age
  - Training
- Can improve VO2 Max up to 20-25
  - Peaks 6 months-2 years after implementing endurance training
  - Typical marathoners can maintain pace using 75-80% VO2 Max for over 2 hr
  - Ultramarathoners able to work for prolonged periods at near 90% VO2 Max
- The ability to perform at higher VO2 Max
  - Probably related to anaerobic threshold
    - Lactic acid accumulation impairs performance
    - Anaerobic threshold can be increased by endurance training
  - Improved anaerobic threshold
    - Allows longer period before anaerobic metabolism dominates
      - Lactic acid accumulation affects performance

References
3. Camargo, C, Simmons, FE. Anaphylaxis: Rapid recognition and treatment. UpToDate Online 16.3 Topic last update 10/10/08

Author: Tony Chang, MD, University of Nevada Reno FPRP

Editor: Carol Scott, MD, University of Nevada Reno FPRP