Chapter 3

Recovery From Exercise

Rest to Exercise Transition
- Exercise metabolism
  - Energy expenditure may increase 15 to 25 x’s rest
  - Provides ATP for contracting skeletal muscles
- Energy utilization may increase 200 times
- Large capacity to produce and use ATP

Rest to Exercise Transition
- Step onto a treadmill at 6 mph
  - In one step muscles increase ATP production
  - What metabolic changes occur?
- From rest to light or moderate exercise
  - Oxygen consumption increases rapidly
  - Steady state reached in 1 to 4 minutes

Rest to Exercise Transition
- Slow adjustment to steady state VO2
  - Suggests anaerobic pathways contribute
- Lag in oxygen uptake at beginning
  - Oxygen deficit
- Steady state
  - ATP requirement met through aerobic ATP production

O2 deficit - difference between the oxygen required and the oxygen consumed

Oxygen Deficit
- Inadequate oxygen consumption during exercise
  - Resulted in oxygen deficit
  - Body borrowed on its energy reserves
  - Extra oxygen consumed (above rest) during recovery-oxygen debt
- Oxygen debt was then used as a measure of anaerobic metabolism during exercise
  - Inadequate for estimating anaerobic metabolism during exercise
Rest to Exercise Transition

- Research suggests
  - ATP-PC system is first active bioenergetic pathway
  - Then anaerobic glycolysis
  - Finally aerobic energy production

- Point
  - Several energy systems are involved and energy produced is by a mixture (overlapping) of metabolic systems

Oxygen Deficit

- Why is the aerobic system activated so slowly
  - Theory 1
    - Inadequate oxygen molecules in mitochondria
    - Oxygen can’t accept electrons in ETC – H₂O
    - If true, then oxygen molecules low in whole body
  - Theory 2
    - Delay due to lack of precursors
    - ETC stimulated by ADP and Pi-low at rest
    - Exercise increases ADP and Pi-stimulates Aerobic
    - “inertia of metabolism”

Oxygen Deficit

- Size
  - Trained vs untrained
  - Trained-lower deficit
    - Better aerobic system
    - Mito adaptations

Recovery from Exercise

- Extra oxygen consumption with recovery
  - "O₂ debt" – so named by A.V. Hill (1923)
- Misconceptions
  - Oxygen debt that needs to be repaid (anaerobic metabolism)
  - Lactic acid is a “dead-end metabolite” that is formed but not removed during exercise
  - Elevated blood La represents oxygen insufficiency in muscle

Recovery from Exercise

- Initially,
  - VO₂ decreased rapidly
  - Bl La did not
- Then
  - VO₂ declined slowly
  - Bl La decreased rapidly
- Fast and slow components

Oxygen Recovery
Recovery from Exercise

- Metabolism remains elevated following exercise
- Magnitude and duration influenced by intensity

Recovery from Exercise

- Fast component
  - Steep decline in oxygen uptake
  - 2 to 3 min
- Slow component
  - Slow decline in oxygen uptake
  - 30 min or longer

Recovery from Exercise

- Traditional view
- Fast
  - Resynthesize stored ATP/PC
  - Replace stores of oxygen
  - 20%
- Slow
  - Oxidative conversion of La to glucose-gluconeogenesis
  - 80%

Fast Component

- Elevated oxygen consumption during
- Alactacid (fast)
  - 1. Replenishment of ATP-PC
  - 2. Resaturation of myoglobin with oxygen
    - 500 mL
    - Important in intermittent exercise
  - 3. Restoration of blood levels of oxygen
  - 4. Energy cost of ventilation
  - 5. Increased heart rate

1. Replenishment of Phosphagens

1. Replenishment of Phosphagens
2. Resaturation of myoglobin

- Myoglobin
  - Transports oxygen
  - Stores oxygen in the muscle
  - 500 mL-provide energy for 2 minutes of resting metabolism
- Figure 3.15
  - 20% of the total energy required from myoglobin stores during 1 h intermittent exercise
- Gradient
  - Capillary → myoglobin → mitochondria

3. Restoration of blood levels

- Body stores 2 L of oxygen
- Lungs
  - 0.25-0.5 L
- Dissolved in body fluids
  - .25L
- Combined with Hb
  - 1 L
- Myoglobin
  - 0.25-0.5 L

Fast Component

- 4. Energy cost of ventilation and HR
  - Muscle contraction
- General Characteristics
  - Declines rapidly in recovery
  - Ranges between 2 and 3 L VO₂
  - 5 to 6 L VO₂ in trained athletes
  - Ranges from 2 to 6 minutes

Slow Component

- 1. Increased core temperature
  - Keeps metabolism elevated
- 2. Energy cost of increased ventilation and HR
  - Muscle contraction
- 3. Increased sodium/potassium pump activity
  - Ion redistribution
- 4. Metabolic effect of catecholamines
  - Elevated metabolic levels
- 5. Glycogen resynthesis
  - Continuous vs intermittent different-why?

6. Fate of Lactic Acid

- Lactate can go through different metabolic pathways
- Proximity is near TCA cycle
  - Gluconeogenic precursor < 10-20%
- Pathway depends on metabolic conditions
  - High La levels, plenty of glycogen
    - Oxidized in TCA cycle
  - Prolonged exercise-exhaustion
    - Glycogen depletion-hypoglycemia
  - gluconeogenesis

- Converted to amino acids – 10%
- Converted to glycogen – 20%
- Oxidized through TCA 60%
  - CO₂ and H₂O
  - Lactate shuttle
    - Type II to Type I
    - Transport through circulation-heart, liver, kidney
Cori Cycle: Lactate as a Fuel

- Lactate to glucose (muscle to liver)
- Gluconeogenesis occurs in liver

Removal of Lactic Acid

Slow Component

- General Characteristics
  - Declines slowly in recovery
  - Ranges from 5 to 10 L (may be as high as 14 L)
  - Larger in athletes in long sprints to 800 m
  - Ranges from 30 to 60 minutes
  - Reduction of LA in blood and muscle
  - Restoration of liver and muscle glycogen begins

Challenges to fast/slow

- Bike ergometer
- Similar intensities
- Varying durations
  - 1 to 3 min exercise
  - Exercise stops, but BI La increases
    - Reaches max during recovery

Fuel Selection

- Protein - < 2% (1 h)
  - 5-15%, 3 to 5 h
- Fat vs CHO
  - Diet
  - Intensity
  - Duration
- High fat diet promotes high rate of fat metabolism
- Low intensity-fat metabolism
- High intensity-CHO metabolism
Exercise Intensity

- Fats primary source
  - < 30% VO2max
- CHO primary source
  - > 70% VO2max
- "Crossover" point
- Causes
  - Recruitment Type II
  - Increasing blood levels of epinephrine

Exercise Duration

- Fat metabolism
  - Lipolysis breakdown
  - Triglycerides
  - FFA, glycerol
  - Lipases
    - Stimulated by EPI, NE
- Low level exercise
  - EPI rises in blood
  - Lipase activity increases
  - Lipolysis occurs

Exercise Duration

- Lipolysis increases blood, fat levels-FFA
- Slow process
- FFA mobilization
  - Inhibited by insulin
  - Inhibited by LA
- Insulin levels decrease in prolonged ex

Exercise Duration

- Consumption of high CHO meal/drink
  - 30-60 min before exercise
  - Increase in blood glucose
  - Increase in insulin levels
  - Decreased lipolysis and fat metabolism

Submax vs Max