**Exercise Metabolism II**

- Oxygen debt & deficit
- Lactate threshold

---

- VO2max, VO2max and Lactate threshold
- CHO and fat metabolism during exercise

---

**Maximal Oxygen Consumption – VO2max**

- Maximal capacity to transport and utilize oxygen
- Measured by incremental or graded exercise tests
- VO2max determined by:
  - Maximum ability of cardiorespiratory system to deliver O2 (trained) and/or
  - Maximum ability of muscles to take up and use oxygen (untrained)

---

**VO2max – trained vs. untrained subjects**

- VO2max is (usually) best expressed as ml/kg/min (not ml/min)
- VO2max increases with aerobic exercise training (to a point)
- This increase in VO2max is associated with increased mitochondrial density, increased Kreb’s cycle enzymes, increased capillarity, increased maximum cardiac output, etc.
**VO2max – average and elite values**

Typical VO2max values:

- Male ~20 yrs old: 44-50 ml/kg/min
- Female ~20 yrs old: 38-42 ml/kg/min
- Elite male athlete: 70-85 ml/kg/min
- Elite female athlete: 60-75 ml/kg/min

VO2max decreases with increasing age after ~30 yrs

---

**Relationship Between VO2max and Lactate Threshold**

- Lactate threshold is often expressed as a percent of VO2max
- ~30% of VO2max is walking
- In untrained people, the lac threshold is at ~50-60% of VO2max
- In trained people, the lac threshold is higher
  - Competitive marathoners run at 75-80% of VO2max – still below their lac threshold
  - Alberto Salazar – an elite marathoner ran at 86% of his measured VO2max
- Both VO2max and lac threshold are used to evaluate aerobic and endurance capacity, fitness

---

**Sources of Fuel During Exercise**

- **Carbohydrate**
  - Blood glucose
  - Muscle/liver glycogen
- **Fat**
  - Plasma FFA (from adipose tissue lipolysis)
  - Intramuscular triglycerides
- **Protein**
  - Only a small contribution to total energy production (5-10%)
    - May increase to >15% late in prolonged (at least > 1 hr) exercise
- **Blood lactate**
  - Oxidation in heart, aerobic muscle
  - Gluconeogenesis via the Cori cycle
Fuel Selection During Exercise

- Fuels vary in the amount of $O_2$ used and $CO_2$ produced during their metabolism.
- Respiratory exchange ratio (RER):
  \[ RER = \frac{VCO_2}{VO_2} \]
- From the RER, the % fat and CHO used for metabolism can be estimated.
- Resting RER is ~0.75 – 0.80

<table>
<thead>
<tr>
<th>RER</th>
<th>%Fat</th>
<th>%CHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>0.75</td>
<td>83</td>
<td>17</td>
</tr>
<tr>
<td>0.80</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>0.85</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>0.90</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>0.95</td>
<td>17</td>
<td>83</td>
</tr>
<tr>
<td>1.00</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Caveat to the use of RER to estimate % fat or CHO metabolism

- RER = respiratory exchange ratio – at the mouth.
- RQ = respiratory quotient – the VCO2/VO2 at the muscle.
- RER does not necessarily equal the RQ.
  - During steady-state in humans RER may equal RQ.
  - RER will not equal RQ during non-steady state or hyperventilation (measuring equipment makes many people hyperventilate at rest).

Exercise Intensity and Fuel Selection

- Low-intensity exercise (<30% VO2max)
  - Fats are primary fuel.
- High-intensity exercise (>70% VO2max)
  - CHO are primary fuel.
- “Crossover” concept:
  - Describes the shift from fat to CHO metabolism as exercise intensity increases.
  - Due to:
    - Recruitment of fast muscle fibers.
    - Increasing blood levels of epinephrine (leads to cAMP and increased glycolysis).
    - Inhibition of lipolysis by high blood lactate concentration.
Illustration of the “Crossover” Concept

Effect of Exercise Intensity on Muscle Fuel Source

Fat Burning: High or Low Intensity Work?

- Considering fuel selection at varying exercise intensities, is there an optimal intensity for “burning fat”?
- Activities that combine a relatively high % fat usage and a high total energy expenditure will have a greater absolute amount of fat oxidation

![Illustration of the “Crossover” Concept](image1)

![Effect of Exercise Intensity on Muscle Fuel Source](image2)

![Fat Burning: High or Low Intensity Work?](image3)
**Exercise Duration and Fuel Selection**

- During prolonged exercise, CHO metabolism gradually decreases while fat metabolism gradually increases.
- Increased rate of lipolysis:
  - Breakdown of triglycerides into glycerol and free fatty acids (FFA)
  - Stimulated by rising blood levels of epinephrine, norep, and glucagon
  - Stimulated by decreasing blood levels of insulin

**Metabolic response to intensity & duration**

<table>
<thead>
<tr>
<th>Intense exercise</th>
<th>Intense exercise</th>
<th>Moderate exercise</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 30 seconds</td>
<td>&gt; 45 seconds</td>
<td>2-3 minutes</td>
<td>&gt; 5 minutes</td>
</tr>
</tbody>
</table>

- = PC-ATP
- = Anaerobic Glycolysis
- = Oxidative Phosphorylation

**Shift From CHO to Fat Metabolism During Prolonged, Moderate Intensity Exercise**

![Graph showing the shift from CHO to fat metabolism during exercise time.](image)
Interaction of Fat and CHO Metabolism During Exercise

- “Fats burn in the flame of carbohydrates”
- Glycogen is depleted during prolonged high-intensity exercise
  - Reduced rate of glycolysis and production of pyruvate
  - Reduced Krebs cycle intermediates, esp. OAA (from glycogen)
  - Free Fatty Acids become Acetyl-CoA which must be oxidized in the Krebs Cycle
  - Thus, reduced CHO availability -- reduced fat oxidation