Working metabolism
Definition

- Energy expenditure during muscle work
  - Contribution to whole metabolism
Energy sources

**Adenosine triphosphate, ATP**
- Adenine
- Ribose
- High energy bond

**Creatine phosphate (CP)**
- For short term, high rates of energy production
- CP + ADP → ATP

**Anaerobic glycolysis**
- Glycogen
- Glucose
- ATP
- ATP
- Lactate

**Oxidative phosphorylation**
- Protein
- Free fatty acids
- Glucose
- Water + Carbon dioxide
Energy sources

- **Phosphagen system**
  - Sprinter
  - 8-10 seconds (100 m)

- **Glycogen-lactic acid system**
  - Swimmer
  - 1.3–1.6 minutes (400 m)

- **Aerobic respiration**
  - Marathon runner
  - Unlimited time (15 Km)
Aerobic load

- Aerobic means with „oxygen“
  - oxygen delivery = organism needs
  - waste products are CO2 and water

- Subgroups:
  - short aerobic – 2 – 8 min (lactat/aerobic)
  - mezzo aerobic – 8 – 30 min (mainly aerobic)
  - longterm aerobic - 30 min and more (aerobic)

- Aerobic endurance is built up by continual and interval running
  - continual running enhances the maximal oxygen usage \((\text{VO2max})\)
  - interval running enhances the effect of heart as a pump

- Aerobic threshold
  - point where organism starts to take energy from anaerobic sources
  - approx. in 65% of maximal heart frequency
Anaerobic load

- Anaerobic means without „oxygen“
  - organism depends upon energy reserves
  - waste products are accumulating, and oxygen debt is created
  - other similar activity is not possible until debt is „paid“
  - lactate and alactate anaerobic load

- Subgroups
  - short anaerobic – less than 25s (mainly alactate)
  - mezzo anaerobic - 25s - 60s (mainly lactate)
  - longterm anaerobic - 60s – 120s (lactate +aerobic)

- Anaerobic endurance is built up by repeating exercise with high load

- Anaerobic threshold
  - point where lactate starts to accumulate in muscles
  - between 85-90% of maximal heart frequency (approx. about 40 bpm higher than aerobic threshold)
**Effect to heart**

- **Athletes**
  - bradycardia – heart rate in rest under 50 bpm
  - ECG – ventricle hypertrophy, early repolarization
  - heart enlargement of X-rays
  - elevated cardial enzymes

- **Exercise zones of heart frequency**
  - resting zone - 60% - 70%
  - aerobic zone - 70% - 80%
  - anaerobic zone - 80% - 90%
  - critical zone 90% - 100%

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### Exercise Zones

<table>
<thead>
<tr>
<th>BEATS PER MINUTE</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>65</th>
<th>70</th>
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<tr>
<td>100%</td>
<td>200</td>
<td>195</td>
<td>190</td>
<td>185</td>
<td>180</td>
<td>175</td>
<td>170</td>
<td>165</td>
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<td>90%</td>
<td>180</td>
<td>176</td>
<td>171</td>
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<td>158</td>
<td>153</td>
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<td>152</td>
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<tr>
<td>70%</td>
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<tr>
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<td>99</td>
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<td>90</td>
</tr>
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<td>90</td>
<td>88</td>
<td>85</td>
<td>83</td>
<td>78</td>
<td>75</td>
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</table>

- VO2 Max (Maximum effort)
- Anaerobic (Hardcore training)
- Aerobic (Cardio training / Endurance)
- Weight control (Fitness / Fat burn)
- Moderate activity (Maintenance / Warm up)
Physical load

- Vessel dilatation in muscles – increase in blood flow and oxygen delivery

- During excessive activity and slower oxygen supply, anaerobic glycolysis starts

- Lactate acid (lactate)
  - 80 % lactate returns back to the liver
After physical load

- When oxygen delivery is sufficient (after activity finishes):
  - Lactate – turns to CO2 and water
  - replenishment of ATP, phosphocreatine, glycogen
  - oxygen returns to hemoglobin, myoglobin and body fluids

- Additional oxygen that needs to be delivered to organism after physical activity is called the oxygen debt (A.V. Hill 1886-1977).
  - Excess Post-exercise Oxygen Consumption (EPOC)

- Replenishment of muscle and liver glycogen
  - carbohydrate diet
  - Several hours and days
Oxygen debt

Two main components of oxygen debt payback:

- alactate oxygen debt (fast component)
  - portion of oxygen needed for synthesis of muscle ATP and PC
- lactate oxygen debt (slow component)
  - portion of oxygen needed for lactate removal from muscle cells and blood
VO2 max

Parameter of stamina/endurance
- maximal amount of oxygen that is organism able to consume/deliver during the load
- ml/min/kg VO2 max
- built up: work between 65 and 85% of max. HR, at least for 20 min, 3-5 a week

Average amount of VO2 max
- men 3.0 l/min
- women 2.0 l/min
- athletes 6.0 l/min
External determinants of VO2

- **Factors**
  - Altitude – lowering pO2 means decrease in VO2max about 7% in altitude of 5000m
  - Age:
    - maximal VO2max is around 20yrs
    - decrease about 30% between the age of 30-65 yrs.
  - Gender:
    - Women have about 20% lower VO2max
    - Different composition, smaller heart with lower heart stroke, lower levels of Hb

<table>
<thead>
<tr>
<th>Vo2 max</th>
<th>Sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;75 ml/kg/min</td>
<td>Endurance Runners and Cyclists</td>
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<tr>
<td>65 ml/kg/min</td>
<td>Squash</td>
</tr>
<tr>
<td>60-65 ml/kg/min</td>
<td>Football (male)</td>
</tr>
<tr>
<td>55 ml/kg/min</td>
<td>Rugby</td>
</tr>
<tr>
<td>50 ml/kg/min</td>
<td>Volleyball (female)</td>
</tr>
<tr>
<td>50 ml/kg/min</td>
<td>Baseball (male)</td>
</tr>
</tbody>
</table>
Internal determinants of VO2

- Cardiac output (the amount of blood pumped out during 1 minute)
- Transport capacity (amount of Hb)
- Amount of muscles
Cardiac output

HRmax = 220 - Age
EF = 65%
Hormonal changes during physical activity

- catecholamines
- ADH
  - antidiuretic hormone
- ACTH, STH, TRH
  - adrenocorticotropic, somatotropic, thyreotropic hormone
- glucocorticoids, mineralocorticoids
- glucagon – insulin
- testosterone