Chapter 11

Methods for Anaerobic Training and Physiologic Response
Training Principles

- To improve one’s ability to perform a certain task involves working SPECIFIC muscles or organ systems at an INCREASED resistance.

- Specificity of Training
  - Identify the predominant energy system
    - ATP-PC
    - Lactic acid
    - Aerobic
Physiologic Factors in Anaerobic Training

Figure 11.2
A summary of the major (orange), intermediate (dark blue), and minor (green) physiological factors in the specificity of anaerobic training and exercise. The interaction among the various components is indicated by double-headed arrows. LA = anaerobic glycolysis or lactic acid system, ST = slow twitch (Type I) fibers, and FT = fast twitch (Type II) fibers.
## Classification of Activities

### 11.2 Various sports and their predominant energy systems

<table>
<thead>
<tr>
<th>Sports or sporting activity</th>
<th>ATP-PC and anaerobic glycolysis</th>
<th>Anaerobic glycolysis and aerobic</th>
<th>Aerobic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aerobic dance</td>
<td>5</td>
<td>15–20</td>
<td>75–80</td>
</tr>
<tr>
<td>2. Baseball</td>
<td>80</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>3. Basketball</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4. Fencing</td>
<td>60</td>
<td>20</td>
<td>negligible</td>
</tr>
<tr>
<td>5. Field hockey</td>
<td>50</td>
<td>20</td>
<td>negligible</td>
</tr>
<tr>
<td>6. Football</td>
<td>90</td>
<td>10</td>
<td>negligible</td>
</tr>
<tr>
<td>7. Golf</td>
<td>95</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>8. Gymnastics</td>
<td>80</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>9. Ice hockey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Forward, defense</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>B. Goalie</td>
<td>90</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10. Ice speed skating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. 500 m</td>
<td>80</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>B. 1000 m</td>
<td>35</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>C. 1500 m</td>
<td>20–30</td>
<td>30</td>
<td>40–50</td>
</tr>
<tr>
<td>D. 5000 m</td>
<td>10</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td>E. 10,000 m</td>
<td>5</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>11. In-line skating, &gt; 10 km</td>
<td>5</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>12. Lacrosse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Goalie, defense, attacker</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>B. Midfielders, man-down</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>13. Rowing</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>14. Skiing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Slalom, jumping</td>
<td>80</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>B. Downhill</td>
<td>50</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>C. Cross-country</td>
<td>5</td>
<td>10</td>
<td>85</td>
</tr>
<tr>
<td>D. Recreational</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>15. Soccer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Goalie, wings, strikers</td>
<td>60</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>B. Halfbacks or sweeper</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>16. Stepping machine</td>
<td>5</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>17. Swimming and diving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Diving</td>
<td>98</td>
<td>2</td>
<td>negligible</td>
</tr>
<tr>
<td>B. 50 m</td>
<td>90</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>C. 100 m</td>
<td>80</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>D. 200 m</td>
<td>30</td>
<td>65</td>
<td>5</td>
</tr>
<tr>
<td>E. 400 m</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>F. 1500 m, 1650 yd</td>
<td>10</td>
<td>20</td>
<td>70</td>
</tr>
</tbody>
</table>

Training Principles

- **Intensity**
  - Considered most important

- **Energy source**
  - Estimated from performance time

- **Training Intensity**
  - Determined from HR at lactate threshold (LT)

*Figure 3-1*  Energy sources for muscle as a function of activity duration. Schematic presentation showing how long each of the major energy systems can endure in supporting all-out work. Source: D. W. Edington and V. R. Edgerton, 1976. Used with permission.
Training Principles

- Anaerobic energy systems
  - Activities lasting less than 3 minutes
    - Met by ATP-PC and glycolysis
  - Activities requiring near maximal muscular force production
    - Sprints—running and swimming

- Specificity of training
  - Training needs to focus on these systems
  - Muscles involved in activity
Training Principles

■ Intensity
  – LT must be determined
  – Training based on HR at LT
  – To increase LT
    ■ Training HR 5 to 15% higher than HR at LT

■ Why?
  – Higher LT
  – Higher intensity before lactate buildup
  – Resulting in improved performance
Training Principles

- Overload Principle
  - Physiologic adaptation occurs
  - Training intensities must be increased
    - Intensity
    - Frequency
    - Duration
Training Principles

- 6 weeks training
  - HR slightly above LT
  - LT-pre to post
  - HR at LT-pre to post
  - THR-pre to post
    - All similar
  - Increased swimming velocity needed to achieve same THR

Figure 11.3
Lactate threshold (LT) before and after a 6-week anaerobic swimming program. Note that the lactate curve is shifted to the right with training. In both tests LT, heart rate at LT, and training heart rate were similar. However, as a result of training, the athlete had to swim at a faster pace to achieve her training heart rate.
Training Principles

Guidelines for frequency and duration

- Intensity
  - HR 5 to 15% above HR at LT

- Frequency
  - 3 to 4 days/week

- Sessions/day
  - 1 or 2

- Duration
  - ATP-PC-repeated work bouts 25 sec or less
  - Glycolysis-repeated work bouts of 3 to 4 min or less
Training Principles

- Aerobic system
  - Important for clearing lactate
  - Regeneration of ATP-PC
  - Useful in sports with anaerobic component interspersed with aerobic component
    - Ice hockey

- Tables 11.6 and 11.7
  - Work rates for interval training prescriptions
Training Principles

- Intervals important - rest
- Partial replenishment of ATP-PC during rest
- \( \text{O}_2 \)-myoglobin restored
- Replenishment primarily through aerobic system
ATP-PC Recovery

Graph showing the amount of stored ATP/CP over time:
- Sprint 6-8 sec
- 1 min
- 2 min
- 3 min
- 4 min
- 5 min

The graph illustrates a sharp decrease immediately after the sprint, followed by a gradual recovery over the subsequent minutes.
Training Principles

Training to improve ATP-PC

- Interval training
- High intensity intervals (5 to 10 sec)
- Rest intervals (30 to 60 s)
- Fitness of individual
Physiologic Basis

- Improved capacity of ATP-PC system to generate ATP
  - Through increased muscular stores of ATP
    - Increase muscular stores of ATP (25%)
    - Increased muscular stores of PC (40%)
  - Increased enzyme activity
    - ATPase – ATP + H₂O ⇌ ADP + Pi
    - Myokinase – ADP + ADP ⇌ ATP + AMP
    - Creatine kinase – ADP + CP ⇌ ATP + C
    - Creatine kinase (mito) – ATP + C → ADP + CP
Training Principles

- Training to improve ATP production by anaerobic glycolysis system
  - Increasing dependence for energy production from An Gly begins after about 10 s of maximal effort
  - High intensity intervals of 20 to 60 s
    - Drastic reduction in muscle glycogen stores
    - Alternate hard and light interval training days
  - Table 11.7 guidelines
Training Principles

- Intensity > 90% $\text{VO}_2\text{max}$
- PC stores
  - Rapid drop, slower drop
- ATP
  - Drops a little
- Muscle lactate
  - Sharp rise
- Blood lactate
  - Rise is less than in muscle
Physiologic Basis

- Glycolytic enzymes (10 to 25% increase)
  - Phosphorylase
  - Phosphofructokinase
  - Lactate dehydrogenase
Training Principles

- Anaerobic training improves muscles capacity to tolerate La that accumulates with anaerobic glycolysis
- $\text{H}^+$ ion thought to interfere
  - Metabolism
  - Contractile process
- Muscle buffering capacity improves with training
  - 12 to 50% with 8 weeks anaerobic training
    - Bicarbonate and muscle phosphates
  - Delays onset of fatigue
Anaerobic Threshold

- AT-exercise intensity (% $\text{VO}_2\text{max}$) above which blood La and $\text{V}_E$ increase disproportionately to oxygen consumption
- Ventilatory breakpoint

![Graph showing VO2 consumption and Blood lactate changes with incremental work.](image)
Anaerobic Threshold

- Theoretically, breakpoints occur because LA easily dissociates into $H^+$ and $La^-$.  
- Excess $H^+$ decreases pH. 
- $H^+$ bind with buffer. 
- $NaHCO_3 + Hla \rightarrow NaLa + H_2CO_3$ 
- $H_2CO_3 \rightarrow H_2O + CO_2$ 
- $CO_2$ is a potent stimulant for respiration.

Figure 4.14
Ventilatory and Lactate Thresholds during Incremental Work to Maximum
Anaerobic Threshold

- Identifying AT
- Systematic increase in VE/VO$_2$ without a concomitant increase in VE/VCO$_2$
- Ventilatory equivalent for oxygen-VE/VO$_2$
- Ventilatory equivalent for carbon dioxide-VE/VCO$_2$

Figure 8.11 Changes in the ventilatory equivalent for carbon dioxide (VE/VCO$_2$) and the ventilatory equivalent for oxygen (VE/VO$_2$) during increasing intensities of running. Note that the breakpoint of the anaerobic threshold at a running velocity of 245 m/min is evident only in the VE/VO$_2$ ratio.
Anaerobic Threshold

The increase in VE/VO$_2$ indicates that the increase in ventilation to remove CO$_2$ is disproportionate to body’s need for oxygen.

Figure 8.11 Changes in the ventilatory equivalent for carbon dioxide (VE/VCO$_2$) and the ventilatory equivalent for oxygen (VE/VO$_2$) during increasing intensities of running. Note that the breakpoint of the anaerobic threshold at a running velocity of 245 m/min is evident only in the VE/VO$_2$ ratio.
Anaerobic Threshold

- The relatively constant VE/VCO₂ indicates that ventilation matches body’s need to remove CO₂.
Anaerobic Training and the Heart

- Weight training
  - ↑ Septum thickens
  - ↑ LV mass
  - ↑ Posterior wall
  - Due to pressure overload

- Endurance training
  - ↑ LV cavity
  - Some increase in wall thickness
  - Due to volume overload