Chapters 13, 21 (pp. 427-430)

The Physiology of Endurance Training
Training for Performance

Aerobic Performance

- To improve endurance performance the athlete must work SPECIFIC muscles or organ systems at an INCREASED RESISTANCE
- Training principles
  - Specificity of training
    - Muscles
    - Energy system – primary source of ATP
  - Progressive overload – adaptation
    - Continue to increase capacity in response to training load
  - Reversibility (detraining)
    - The training effect lost when training is stopped

Training Principles

- Intensity
  - 60-90% max HR
  - Age predicted
- Duration
- Frequency

Training to Improve Aerobic Power

- Three primary methods
  - Interval training
  - Long, slow distance
  - High-intensity, continuous exercise
- Intensity appears to be the most important factor in improving VO\textsubscript{2max}

Interval Training

- Advantage
  - Perform larger amounts of high-intensity exercise in short time
- Overload
  - Increase the number of exercise intervals
  - Increase the intensity of the work interval

Interval Training Session

- Length of the work interval
  - Longer than 60 s
- Intensity of the effort
  - 85-100% HRmax
- Duration of the rest interval – time between work bouts
  - Light activity-walking
  - Expressed as a ratio to the work interval
Long, Slow Distance
- Low intensity exercise
  - 60% VO_{2max} or 70% HR_{max}
- Duration greater than expected in competition
- Based on the idea that training improvements are proportional to the volume of training
- Short term, high intensity exercise now found to be superior to long term, low intensity

High Intensity, Continuous Exercise
- Excellent method for improving
  - VO_{2max}
  - Lactate threshold
- Intensity 80-90% VO_{2max}
- Determine HR at lactate threshold
  - Train at or slightly above that level
- Duration of 25-50 min
  - Depends on individual fitness level

Training Intensity and Improvement in VO_{2max}

![Graph showing improvement in VO_{2max} vs. training intensity](image)

Training Principles
- Intensity
  - 60-90% HR_{max}
  - 50-85% VO_{2max}
- Frequency
  - 4 to 6 days/week
- Duration
  - 25 min – fast, with 5 min slow work intermittently
  - >30 min if slow, continuous

Influences on Training
- Men and women respond similarly to training programs
- Training improvement is always greater in individuals with lower initial fitness
- Genetics plays an important role in how an individual responds to training

Aerobic Training-Muscle
- Skeletal muscle adaptations
  - Muscle fiber type
    - Reliance primarily on ST fibers
    - 7 to 22% increase in size
    - Fiber size varies considerably in athletes
    - Little relationship between muscle fiber sizes in endurance athletes and aerobic capacity
Aerobic Training-Muscle

- Muscle fiber type
  - Size probably more critical in anaerobic events
  - Type 2b take on characteristics of Type 2a

- Capillary supply
  - Increase in the number of capillaries surrounding each muscle fiber
  - 5 to 10% more capillaries in trained vs untrained
  - 15% increase when sedentary trained
  - Decreased peripheral resistance

- Capillary supply
  - Greater exchange of gases, heat, nutrients and waste
  - Changes occur in first few weeks

- Myoglobin content
  - Stores oxygen and releases it to mito when needed
  - Increases 75-80% with training

- Oxidation of glycogen
  - Aerobic glycolysis

Skeletal Muscle Enzymes

<table>
<thead>
<tr>
<th>Table 8.2</th>
<th>Selected Muscle Enzyme Activities (umol - g(^{-1}) - min(^{-1})) for Untrained, Aerobically Trained, and Aerobically Trained Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untrained</td>
</tr>
<tr>
<td>Aerobic enzymes</td>
<td></td>
</tr>
<tr>
<td>Oxidative system</td>
<td></td>
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<td>Succinate dehydrogenase</td>
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<tr>
<td>Malate dehydrogenase</td>
<td>46.5</td>
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<td>Carnitine palmitoyl transferase</td>
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<tr>
<td>Aerobic enzymes</td>
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<td>ATP-PC system</td>
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<td>Creatine kinase</td>
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<td>Myokinase</td>
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<td>Glycolytic system</td>
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<td>Phosphorylase</td>
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<td>Phosphofructokinase</td>
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<tr>
<td>Lactate dehydrogenase</td>
<td>786.0</td>
</tr>
</tbody>
</table>

Note: Enter significant differences from the untrained value.

Aerobic Training-CV

- Rest
  - Cardiac hypertrophy
  - Increased LV cavity
  - Increased EDV, smaller ESV, greater EF

Differences in:
(a) and diastolic volume (EDV),
(b) and end systolic volume (ESV), and
Aerobic Training-Rest

- Cardiac hypertrophy
  - Increased contractility of heart
    - Increase in release and transport of Ca++ from SR
  - High correlation between heart size and SV

- Decreased heart rate
  - Bradycardia
  - Increase in vagal tone-PS innervation
  - Decrease sympathetic tone
  - Combination of Sym decrease and PS increase

- Decreased HR
  - Intrinsic rate of SA node

- Increased levels of ACH found in atria following endurance training
- Decreased sensitivity to circulating catecholamines
- Changes in cardiac dimensions altering mechanical effects (wall thickness)

- Lung Volumes
  - Little change with training
  - Increased capillary density and hypertrophy of skeletal muscle
  - Increased blood volume

- Increase in SV at rest
  - Increased contractility
  - Decreased HR-
    - Longer filling time, greater stretch

- Plasma Volume
  - Contributes to ↑ SV

- Hematocrit
  - ↓ due to PV expansion

- Hb
  - Doesn’t usually change
Aerobic Training-Rest

- Plasma volume reduction with acute exercise
- Plasma volume expansion with chronic exercise
  - Increased release of ADH and aldosterone
    - Causes kidneys to retain water
  - Increased plasma protein content
    - Increases osmotic pressure

Aerobic Training-Exercise

- Submax
- Max
- Little or no change
- Significant increase
  - Mechanical efficiency increase
  - Less wasted motion
  - \( Q \) and \( a-V_O_2 \) diff

- Submax
- Max
- Little or no change
  - Increase due to SV
  - May be due to \( a-V_O_2 \)

- Submax
- Max
- Little or no change
  - \( Sym \) tone
  - \( PS \) tone
  - \( circ \) NE, E
  - \( SV \)
  - \( Sym \) drive
  - Intrinsic SA rate
Aerobic Training

- Exercise
  - Submax
  - ↑ capillarization
  - ↑ a-vO₂ diff
  - Max
  - ↑ mito adaptations
  - ↑ cap density
  - ↑ myoglobin
  - vasodilation

Greater pulmonary diffusion
- Lung volumes
  - Increased Vₑ at max (15 to 25%) with training
  - TV
  - R

VO₂ max = 52 ml/kg/mi
- 2 years of training
- VO₂ max = 71 ml/kg/mi
- Races at 75%
- 2 more years
- VO₂ max = 71 ml/kg/mi
- Races at 88%

How much will VO₂ max increase?
- Literature reports 4 – 93%
- Low initial values-large increase
  - Ekblom, 1969
  - 2 to 3 years of training
  - 44% increase (45 to 65 ml/kg/min)

How much will VO₂ max increase?
- High values-small increase
  - 16% increase (2 to 3 months)
  - 44 to 51 ml/kg/min
- On average 15 to 20% increase training at 75% VO₂ max for 6 months
- VO₂ max = Q x a-vO₂ diff
  - Central vs peripheral changes
Maximal Oxygen Consumption

- How does VO$_{2\text{max}}$ increase?
  - Or
  - What are the changes in the CV system that permit an increase in VO$_{2\text{max}}$?
  - VO$_{2\text{max}}$ = Q x a-VO$_2$ diff
    - Central and peripheral adaptations

Maximal Oxygen Consumption

- Wilmore et al. 1976
  - Sedentary, trained 2 or 3 months
  - VO$_{2\text{max}}$ increased by 16%
    - 8% increase in maximal cardiac output
      - Entirely to increased SV
    - 8% increase in a-VO$_2$ difference

Maximal Oxygen Consumption

- Ekblom et al. 1968
  - Training >2 years
  - VO$_{2\text{max}}$ increased 40%
    - 32% increase in SV
    - 8% increase in a-VO$_2$ difference

Maximal Oxygen Consumption

- Conclusions
  - Central and peripheral adjustments to physical conditioning are a function of:
    - Age
    - Initial level of VO$_{2\text{max}}$
    - Mass of the muscle(s) conditioned
  - On average 15 to 20% increase training at 75% VO$_{2\text{max}}$ for 6 months

- High VO$_{2\text{max}}$ values—how much do they increase?
  - Little change after years of intense conditioning
  - Genetically predetermined?
  - Dependent on activity during childhood?
- Range (30 ml/kg/min to 85 ml/kg/min)
  - Range of adaptation small
Symptoms of Overtraining

- Decrease in performance
- Loss of body weight
- Increased number of infections
- Chronic fatigue
- Psychological stress
- Elevated heart rate and blood lactate levels during exercise