Exercise and cardiovascular system

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CV Adaptations

Maximal cardiac output

↑ Stroke volume

↑ "Preload"

Peripheral

Capillaries

Mitochondria

Muscle blood flow

↓ "Afterload"

↓ Sympathetic N.S. activity to working muscle

↑ a-\(\bar{V}\)O\(_2\) difference

↑ \(\bar{V}\)O\(_2\) max
CV Adaptations

Central – heart
- 10-25% overall improvement
- Moderate decline with inactivity

Peripheral – muscle
- 50-300% overall improvement
- Rapid decline with inactivity
Effects of Aerobic Training on Cardiovascular Function

- Heart rate
- Stroke volume
- a-v $O_2$ difference
- Cardiac output
- VO2
- Systolic blood pressure
- Diastolic blood pressure

<table>
<thead>
<tr>
<th>Additional Measurements</th>
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</thead>
<tbody>
<tr>
<td>Coronary blood flow</td>
<td>Blood volume</td>
</tr>
<tr>
<td>Brain blood flow</td>
<td>Plasma volume</td>
</tr>
<tr>
<td>Blood volume</td>
<td>Red blood cell mass</td>
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<tr>
<td>Heart volume</td>
<td></td>
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</table>
Training has little effect on resting VO2

Example, running at 8 mph at a 0% grade is always at VO2 of ~24.9 ml/kg/min

Training increases maximal VO2 (VO2max)

15-20% (but as high as 50%) increase.
VO2max

Training to increase VO2max
- Large muscle groups, dynamic activity
- 20-60 min, 3-5 times/week, 50-85% VO2max

Expected increases in VO2max
- 15% (average) - 40% (strenuous or prolonged training)
- Greater increase in highly deconditioned or diseased subjects

Genetic predisposition
- Accounts for 40%-66% VO2max
VO2max

- Higher Q at max
- High a-v O2 difference
CARDIAC OUTPUT

- No change at rest
- No change at submax exercise
- Increased at maximal exercise
HEART RATE

- Lower resting HR
  - Parasympathetic stimulation
  - Not always a true indicator of fitness level

- Lower submaximal heart rate
- Small effect on maximal heart rate
STROKE VOLUME

- SV: 20% higher
- all conditions
- Larger heart size
- Increase EDV
- Increase blood volume
- Increase contractility
- Increase Ca release in myocardium
- Similar ESV
- Greater ejection fraction due to higher EDV
STROKE VOLUME

Stroke volume may continue to increase up to maximal effort in trained individuals.
Stroke Volume

- End diastolic volume ("preload")
- Contractility
- Total peripheral resistance ("afterload")
- Plasma volume
- Filling time and venous return
- Ventricular volume
Myocardial Hypertrophy

- Aerobic training: Thicker walls and greater volume
- Strength training: Thicker walls only
- Pathological: Thicker but weaker walls
BLOOD VOLUME

- Increased total blood volume
- Increased plasma volume
- Increased red blood cells
- Decrease in hematocrit (44 to 41)
Blood Volume

- Total blood volume: 5.0 to 5.8 (14%)
- Red blood cells: 2.2 to 2.4 (8%)
- Plasma volume: 2.8 to 4.3 (35%)
- Hematocrit: 44 to 41.
A-V O2 DIFFERENCE
A-V O2 DIFFERENCE

- a-vO2 difference: slightly greater
- Why?
- Mitochondria
  - Increase in aerobic enzymes
    - Citrate synthase
    - 3-hydroxyacylCoA dehydrogenase
- Myoglobin
- Capillaries
- Hemoglobin
CV Function and Endurance Training

- Increase in parasympathetic inhibition of the SA node (mostly at rest)
- Decrease in sympathetic stimulation (mostly during exercise)
CV Function and Endurance Training

- Increase in EDV (increase chamber size)
- Endurance training
- Increase myocardial mass (increase force of contraction)
- Strength training
## CV Function and Endurance Training

<table>
<thead>
<tr>
<th></th>
<th>At rest</th>
<th>Submax. Ex</th>
<th>Max. Ex</th>
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<tbody>
<tr>
<td>Heart Rate</td>
<td>⬇</td>
<td>⬇</td>
<td>⬇</td>
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<tr>
<td>Stroke Volume</td>
<td>⬆️</td>
<td>⬆️</td>
<td>⬆️</td>
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<tr>
<td>Cardiac Output</td>
<td>⇐️</td>
<td>⇐️</td>
<td>⬆️</td>
</tr>
<tr>
<td>Heart Size</td>
<td>⬆️</td>
<td>⬆️</td>
<td>⬆️</td>
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<tr>
<td>Blood Volume</td>
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<td>⬆️</td>
<td>⬆️</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>⬆️</td>
<td>⬆️</td>
<td>⬆️</td>
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<tr>
<td>Capillary Density</td>
<td>⬆️</td>
<td>⬆️</td>
<td>⬆️</td>
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LACATE LEVELS

Blood lactate levels

Increase removal. Why?
1. Increase capillaries
2. Decrease sympathetic stimulation causes an increase blood flow to heart, liver, and type I muscle fibers

Decrease production. Why?
1. ?
Blood Lactate Levels

![Graph showing blood lactate levels compared to % VO2max for trained and untrained individuals.](image)
BLOOD PRESSURE

- Greatest effect on high blood pressure
- Systolic: lower resting and submax
  - 10 mm Hg decrease
- Diastolic lower maximum
- Why?
  - Weight loss
  - Reduce sympathetic stimulation
  - Other
BLOOD FLOW

- Blood flow
- Coronary: higher at rest, submax, and max.
- Greater SV and lower HR cause a reduction in mVO2.
- Greater vascularity only in diseased hearts
BLOOD FLOW

- **Skeletal blood flow**
  - Increase vasularity (capillaries)
    - Increased O2 and fuel delivery
    - Decrease resistance & decrease afterload & increase Q
  - Decrease flow at submax exercise
    - Compenstated by an increase O2 extraction
    - Greater blood flow to skin
- **Increase flow at maximal exercise (10%)**
  - Due to greater Q and vasularity
Training the CV System

• EXERCISING FOR HEALTH

  • Intensity:
    - 65-90% of HR max or 50-85% of HR reserve (HHR = HR max - HR rest)
    - RPE of 12-15

  • Duration: 20-60 minutes

  • Frequency: Most days of the week
TRAINING THE CARDIOVASCULAR SYSTEM

1. Over Distance Training
2. High-intensity, Continuous Exercise
3. Interval Training
OVER DISTANCE TRAINING

- Description: Long distances at less than competitive pace (50-70%)

- Results:
  - Increase in mitochondria
  - Increase in capillaries
  - Increase fat oxidation

- Benefit: Increased endurance
HIGH INTENSITY, CONTINUOUS TRAINING

Description: Moderate distances at or near competitive pace; 70-90%

Results:
- **Strengthened heart** (increase O2 supply to muscles)
- Decrease in lactate production

Benefit: Increased lactate threshold
INTERVAL TRAINING

- Shorter distances above lactate threshold with periods of rest.
- Able to perform large amount of high-intensity exercise

Results:
- Increase lactate removal
- Increase neural stimulation
- Increase anaerobic energy

Benefit: Improved in speed
LACTATE REMOVAL

Lactate from FT muscle fiber can be cleared or removed at:

1. Heart
2. Liver
3. ST muscle fibers
Training Induced Right Shift in Lactate Curve
Oxygen Efficiency

![Graph showing oxygen uptake vs. running speed for Runner A and Runner B.]

- Runner A
- Runner B

Oxygen uptake (ml · kg⁻¹ · min⁻¹)

Running speed, m/min (mph)

- 11.3 (7.0)
- 12.9 (8.0)
- 14.5 (9.0)
- 16.1 (10.0)
CARDIOVASCULAR DISEASE
Cardiovascular diseases

- Hypertension (high blood pressure);
- coronary heart disease (CHD);
- cerebrovascular disease (stroke);
- peripheral vascular disease;
- heart failure;
- rheumatic heart disease;
- cardiomyopathies (structural abnormalites).
Environmental factors are important in the aetiology of CHD

- CHD death rates vary widely in different countries.
- Rates show strong, temporal changes, e.g. between 1990 and 2000:
  - there was a 40% decrease in UK, Australia and Norway;
  - but
  - a 40% increase in Belarus; and
  - a 60% increase in the Ukraine.
Early events of atherosclerosis within the intima
Narrowing of a coronary artery by a large plaque of atheroma
Natural history of atherosclerosis: from fatty streak to clinical ‘horizon’
Only current physical activity is protective – sports participation in youth does not confer protection in middle-age unless activity is maintained.
Changes in activity or fitness are associated with changes in risk

- Cohort studies have reported assessments of physical activity or fitness made several years apart.

- Harvard Alumni who were sedentary on first observation but became physically active had a lower risk than those who remained sedentary.

- In the Aerobics Center Study, men who were unfit on first assessment but had improved their fitness five years later experienced a much lower CVD risk than those who remained unfit.
The relationship between physical activity/fitness and risk for CHD is:

- consistently reported and inverse;
- strong (relative risk similar to that associated with smoking, high cholesterol and hypertension);
- independent of known confounders;
- graded, i.e. a dose-response has been demonstrated;
- evident in both men and women;
- seen in racially diverse groups.
**Major risk factors for CVD**

**Modifiable risk factors**
- Dyslipidaemia: elevated total cholesterol or low-density lipoprotein cholesterol concentrations, depressed high-density lipoprotein cholesterol concentrations, elevated triglyceride concentrations
- Hypertension
- Cigarette smoking
- Obesity (particularly central/abdominal obesity)
- Hyperglycaemia or diabetes

**Non-modifiable risk factors**
- Family history: risk is increased in first degree relatives (parents, siblings and offspring) of people with premature atherosclerotic disease (men < 55 years and women < 65 years)
- Age: higher risk in older individuals
- Gender: higher risk in males than females
- Ethnic background: higher risk in South Asians although this may be due to the higher prevalence of diabetes in this group
Diameter of coronary arteries of prolific marathoner were two to three times normal: note large lumens.
## Blood pressure classification for adults

<table>
<thead>
<tr>
<th>Blood pressure category</th>
<th>Systolic blood pressure (mm Hg)</th>
<th>Diastolic blood pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>&lt; 120</td>
<td>and</td>
</tr>
<tr>
<td>Normal</td>
<td>120–129</td>
<td>and</td>
</tr>
<tr>
<td>High normal</td>
<td>130–139</td>
<td>or</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>140–159</td>
<td>or</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>160–179</td>
<td>or</td>
</tr>
<tr>
<td>Stage 3 hypertension</td>
<td>≥ 180</td>
<td>≥ 110</td>
</tr>
</tbody>
</table>
Summary I

• Cardiovascular diseases are a major cause of mortality and morbidity in developed countries, and their prevalence is increasing in developing countries.

• Atherosclerosis is the major cause of CVD. It has a long clinical history and may be well-progressed before symptoms occur.

• Inactivity and low fitness are strong risk factors for CHD. Both confer an increase in risk similar to that associated with smoking, hypertension and high blood cholesterol.
Summary II

• Being physically active or fit may reduce the risk of having a stroke.

• Mechanisms by which physical activity may modify CVD risk include effects on lipoprotein metabolism, blood pressure and endothelial function.

• Physical activity is a central component of cardiac rehabilitation. Exercise training may enhance myocardial perfusion and hence oxygen delivery to the heart.

• Exercise reduces symptoms of claudication and heart failure and may help to lower blood pressure in hypertensive individuals.
Thank You!