VO2 Max
Bell Work

Review **Total Lung Capacity**

(page 337 and 338 of Body Structure and Function book)

*This information was discussed at length in A&P classes.

Use your worksheet and write down brief descriptions of each component of total lung capacity.
10) Review the gross and cellular anatomy and physiology of the respiratory system and explain the ventilation process.

Develop an exercise program and a rehabilitation plan for a patient/client who has chronic obstructive pulmonary disease (COPD) and one who is training for a marathon, based on their respective respiratory needs. Compare and contrast these plans to justify the components included.
Objectives

- To define VO2 max.
- To identify and explain the factors that affect VO2 max.
- To understand the different tests to determine VO2 max and critiquing each of these.
What is VO2 max?

“The maximum volume of oxygen inspired, transported and utilised per minute during exhaustive exercise."

(It is measured in ml/kg/min)
VO2 max

- An untrained athlete may only be able to work up to 50-60% of their VO2 max before fatiguing.
- However, a trained athlete can work in excess of 85% of their VO2 max before fatiguing.

- What is the difference between a trained and untrained athlete?
Factors affecting VO2 max

There are 4 main factors that affect a person's VO2 max; Can you name them?

1. Physiological make-up
2. Age
3. Gender
4. Training
Physiological make-up

Effect on VO2 max:

- The greater the efficiency of the cardiovascular system, respiratory system and muscle cells, to inspire and use oxygen, the higher the VO2 max.

- Basically, “How well your heart, lungs, and muscles use oxygen.”

Explanation:

- More air inspired due to strong respiratory muscles.
- **Capillarization**: Increased surface area for gaseous exchange.
- **Cardiac hypertrophy**: Hemoglobin in the blood can then carry more oxygen.
- Can be **genetic**.
- Increased number of **myoglobin** (more O2 stored).
Age

Effect on VO2 max:

- From your early 20’s VO2 max declines by approximately 1% per year.

Explanation:

- As you age, you gradually lose elasticity in the heart, blood vessel and lung tissue walls. This reduces your efficiency in inspiring and transporting oxygen.

- What does efficiency mean?

- Are military physical fitness standards different for various ages? What should the military predict for a soldier coming in at 18 and staying active until retirement?
Effect on VO2 max:

- **Females** tend to have a **15-30% lower** VO2 max than males of the same group

Explanation: (Body composition)

- Females have a **higher % body fat**.
- Females also have **smaller lung volumes, SV, CO and hemoglobin levels**.
- SV is **stroke volume** and CO is **cardiac output**. These were discussed in A&P and will be discussed in later lessons. Basically they deal with **how well the heart works** (its efficiency).
- **Does this mean that all men have greater VO2 than all women? Explain?**
- **Military Physical Fitness Standards?**
Training

Effect on VO2 max:

- **Aerobic training should increase VO2 max by 10-20%**.
- In aging performers, this increase will **counteract** the their VO2 max decline that occurs from aging.
- Based on previous lessons, what is an example of aerobic exercise? What is the difference between aerobic and anaerobic?

Explanation:

- Aerobic training results in increased strength of respiratory muscles and levels of hemoglobin, myoglobin and mitochondria.
- **What does our mitochondria do?**
Contextualizing VO2 max

Which of these athletes requires a greater VO2 max and why?
Top 8 recorded VO2 max results.

**What do you notice about the sports they participate in?**

<table>
<thead>
<tr>
<th>score</th>
<th>name</th>
<th>sport</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.5</td>
<td>Oskar Svendsen</td>
<td>Cycling</td>
<td>18 year old from Lillehammer, Norway. The test was conducted in Sept 2012 at the University College of Lillehammer by physiologist Joar Hansen. (from an article on procycling)</td>
</tr>
<tr>
<td>96.0</td>
<td>Espen Harald Bjerke</td>
<td>Norwegian cross country skier</td>
<td>This score was achieved in 2005 (7.3 liter/min, 76 kg body weight), listed in an article on <a href="http://www.fasterski.com">www.fasterski.com</a>.</td>
</tr>
<tr>
<td>96.0</td>
<td>Bjørn Daehlie</td>
<td>Norwegian cross country skier</td>
<td>This score is commonly quoted, though another source has him recording a best of 90 ml/kg/min.</td>
</tr>
<tr>
<td>93.0</td>
<td>Kurt Asle Arvesen</td>
<td>Road Cycling</td>
<td>a Norwegian professional road bicycle racer for Team Sky. Figure taken from an article published on syklingens verden website, said to be from 1997 (link no longer available).</td>
</tr>
<tr>
<td>92.5</td>
<td>Greg LeMond</td>
<td>cycling</td>
<td>US professional cyclist</td>
</tr>
<tr>
<td>92.0</td>
<td>Matt Carpenter</td>
<td>runner</td>
<td>Pikes Peak marathon course record holder</td>
</tr>
<tr>
<td>92.0</td>
<td>Tore Ruud Hofstad</td>
<td>Norwegian cross country skier</td>
<td>achieved in 2005</td>
</tr>
<tr>
<td>91.0</td>
<td>Gunde Svan</td>
<td>Swedish XC-skiier</td>
<td>won a total of 4x gold, 1x silver and 1x bronze medals at the Winter Olympics.</td>
</tr>
</tbody>
</table>
Jigsaw Activity: Research Testing VO2 Max

Your expert group will research the information. Everyone must document it in their notes. Then we will move to different groups and “teach” the information to our new group.

There are **FOUR aerobic capacity tests** that we use when assessing / improving someone's VO2 max:

1. Direct Gas Analysis
2. Cooper Run (12 minutes)
3. Queens College Step Test
4. NCF Multi-Stage Fitness Test

For each test, you must be able to identify:

- What the test is?
- How is it performed?
- Advantages?
- Disadvantages?
Direct Gas Analysis

- The subject performs **continuous** exercise at **progressive intensities** (gradually increases) until they request to stop.

- Any **expired air is captured by a mask** that you wear throughout, which is connected to a flow meter and gas analyzer.

- The **concentration of O2 and CO2** in inspired air to expired air is **measured**.

- This can then be calculated into a VO2 max figure.
Direct Gas Analysis – Exam Focus (Discuss/Analyze)

Advantages:

- **Direct** objective measurement of VO2 max.
- **Accurate, valid and reliable.**
- Can be performed to a **range** of exercises (e.g. running, cycling, rowing).
- Can be in a **lab or a field** setting.

Disadvantages:

- **Exhaustion.** Pushed to the limit.
- **Cannot be used with the elderly or certain health conditions.**
- **Access** to specialist equipment.
- Dependent on the person's **opinion** of when they cannot continue (e.g. laziness etc...).
Cooper Run

● 12 minute continuous run.

● Aim to travel as far as possible in that time.

● Often done on a 400m track with a cone every 100m.

● The participant is informed of the time remaining after each lap.

● The total distance is then recorded after time is up (laps x 400m etc...).
Cooper Run

From this data, you can use the following conversions to determine your VO2 max.

<table>
<thead>
<tr>
<th>VO2 max</th>
<th>Cooper in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>1600</td>
</tr>
<tr>
<td>34</td>
<td>2000</td>
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<tr>
<td>42</td>
<td>2400</td>
</tr>
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<td>55</td>
<td>2600</td>
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<td>2700</td>
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<td>60</td>
<td>2900</td>
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<tr>
<td>62</td>
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<td>3100</td>
</tr>
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<td>3200</td>
</tr>
<tr>
<td>67</td>
<td>3300</td>
</tr>
<tr>
<td>68</td>
<td>3400</td>
</tr>
<tr>
<td>70</td>
<td>3500</td>
</tr>
</tbody>
</table>
Cooper Run – Exam Focus (Discuss/Analyze)

Advantages:

- Large groups can complete it.
- Can be indoors or outdoors.
- Simple and cheap.
- Individual can perform this alone.
- Published table of normative data provided and simple VO2 max calculation.

Disadvantages:

- Prediction of VO2 max, not an actual measurement.
- Subjects motivation may affect results.
- Cannot be used with the elderly.
- Not sport specific (rowers / cyclists disadvantaged.)
Queens College Step Test

- Participant performs continuous stepping on and off a box (41.3cm high) for exactly 3 minutes.

- You must count your steps as you go (or ask a partner to count for you).

- Normative data:
  - Males = 24 steps/min
  - Females = 22 steps/min
Queens College Step Test – Exam Focus (Discuss/Analyze)

Advantages:
- Sub-maximal test.
- Simple and cheap.
- HR easily monitored.
- Published tables of normative data and simple calculation to VO2 max.

Disadvantages:
- Prediction of VO2 max, not a measurement.
- HR recovery affected by prior food, exercise and fluids.
- Not sport specific (e.g. rowers / cyclists disadvantaged).
- Step height disadvantages smaller subjects; shortness
NCF Multi-Stage Fitness Test

- Subjects perform continuous 20m shuttles at progressive intensities until exhaustion.

- Each shuttle is timed to an audio cue (e.g. a beep).

- The test is over when the athlete can no longer complete the shuttle in the allocated time.

- A level and a shuttle number will then be given, which can be used against a standardised comparison table, to determine a VO2 max value.
NCF Multi-Stage Fitness Test – Exam Focus (Discuss/Analyze)

Advantages:

- Large groups can complete at one time.
- It is simple and cheap to set up and run.
- There are provided normative data tables.

Disadvantages:

- Prediction of VO2 max, not a measurement.
- Dependent on subjects motivation.
- Cannot be used with the elderly / some health conditions.
- Not sport specific.
Video

- https://www.youtube.com/watch?v=NlbqkKFgBhw
End of lesson recap

- Each table needs a blank piece of paper and a 1 pen (preferably coloured).
- Each table will be given a different topic to write on their piece of paper.
- As a table, you have 30 seconds to write one piece of information about that topic on the sheet.
- Pass the sheets clockwise to the next group. Now each group must add an extra piece of information to their new sheet.
VO2 max, Training Zones and Training Methods
Lesson Outcomes

● To recap VO2 max (definition / influencing factors / testing etc...)

● To understand how and why training zones are used.

● To identify and describe different training methods used to increase aerobic capacity.
Recap Quiz

● What are the 4 factors that can affect a person's VO2 max?

● Using a graph, show how age affects VO2 max?

● Why isn't the Queens College Step Test a effective method of assessing VO2 max?

● Why is the Cooper Run an effective method of assessing VO2 max?

● What is Direct Gas Analysis?
Training Zones

To improve VO2 max, athletes must train at the correct intensity.

- What happens if the athlete is working too hard?         Anaerobically
- What happens if the intensity is too low?                No adaptations
- Can an athlete assess their VO2 max during a session?   No
Training Zones

So, what can we use instead to measure the intensity of our exercise?

- Heart Rate

To ensure adaptations are made and your aerobic capacity increases, you must be working within your ‘aerobic zone’.
Maximum Heart Rate

How do we work out Max HR?

220 - Age = Max HR
If I’m 25 years old and want to improve my aerobic fitness, what should my average heart rate be while exercising?
Karvonen's Principle

- Taking age and RHR into account, Karvonen's principle can be used to calculate the correct training HR within a particular zone.

- Maximum HR = 220 - age (in years). **What is your Max HR?**

- Training HR = Resting HR + ___% (Max HR - Resting HR).

- On a whiteboard, try to work out your required HR to be working at 75%?
1. Continuous training

2. Fartlek Training

3. High Intensity Interval Training (HIIT)
Continuous Training

- Steady low-moderate exercise for a long period of time.
- Intensity: 60-80% of max HR.
- Involves large muscle groups.
- Aerobic energy system and slow oxidative muscle fibres (Type 1) used.
- E.g. Road cyclists, long distance runners, triathletes, swimming etc...
Fartlek Training

- Swedish for ‘speed play’.
- Training on different terrains at different intensities.
- Both aerobic and anaerobic systems to be stressed, allowing for recovery while performing.
- E.g. Often team game players, football, rugby, fell runners etc...
High Intensity Interval Training

- Periods of work followed by periods of recovery.

- Several variables to manipulate (duration, intensity, reps, sets, recovery time and activities during recovery etc...).

- Usually 20-60 minutes in total.

- **Work intervals:** 80-95% of max HR. (Duration: 5 secs - 8 minutes).
- **Recovery intervals:** 40-50% of max HR. (Duration: Same as work interval).
Adaptations

Explain the adaptations following a training plan to develop VO2 max:

**Respiratory Adaptations (4)**

**Cardio Vascular Adaptations (5)**

**Musculo-skeletal Adaptations (4)**

**Metabolic Adaptations (3)**

Exam Hint: 16 adaptations may tempt the examiner to set a longer question on this topic. Maybe (10 marks):
Respiratory Adaptations:

- Stronger respiratory muscles (increased max lung volume).
- Increased SA of alveoli (Increased external gaseous exchange).
- Decreased breathing rate and increased volume of O2 in the blood.
- Delays OBLA / fatigue.
Cardiovascular Adaptations:

- Cardiac hypertrophy (SV= increased at rest and exercise. CO= increased at rest only).
- Increased elasticity of alveoli walls (increased vasodilation and vasoconstriction. Decreased blood pressure).
- Increased blood / plasma volume (aids blood flow).
- Increased red blood cells / haemoglobin (increased O2 carrying capacity).
- Capillarisation (increased surface area for blood flow, so more gas exchange).
Musculo-skeletal Adaptations:

- Type 1 muscle fibre hypertrophy (stronger, so decrease in energy cost).
- Increased size of mitochondria (aerobic energy production increased).
- Increased myoglobin and glycogen stores.
- Increased bone strength / density (reduced injury risk).
Metabolic Adaptations:

- Increased activity of aerobic enzymes (breaks down glycogen quicker).
- Decreased fat mass (increased metabolic rate and breakdown of triglycerides).
- Decreased insulin resistance (Prevent type II diabetes).
Ellie, who is 25, wants to train at 75% of her Maximum heart rate in order to improve her aerobic capacity.

1. Using Korovan’s Principle, what should her average heart rate be during exercise?

2. And... What method of training can she use to achieve this?
## Adaptations Recap Quiz

As a table, categorise the following adaptations into the 4 areas (respiratory, metabolic, CV and musculo-skeletal);

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased surface area of alveoli.</td>
<td>R</td>
</tr>
<tr>
<td>Increased blood / plasma volume.</td>
<td>CV</td>
</tr>
<tr>
<td>Delays OBLA.</td>
<td>R</td>
</tr>
<tr>
<td>Increased bone density.</td>
<td>M-S</td>
</tr>
<tr>
<td>Capillarisation.</td>
<td>CV</td>
</tr>
<tr>
<td>Decreased fat mass.</td>
<td>M</td>
</tr>
<tr>
<td>Decreased insulin resistance.</td>
<td>M</td>
</tr>
<tr>
<td>Increased number of haemaglobin.</td>
<td>CV</td>
</tr>
<tr>
<td>Increased enzyme activity.</td>
<td>M</td>
</tr>
<tr>
<td>Hypertrophy of Type 1 muscle fibres.</td>
<td>M-S</td>
</tr>
</tbody>
</table>
● Each table will start with a different long answer question.

● As a group, you must choose one statement to add to the sheet that would equate to 1 mark.

● Once this is done, pass the sheets round the tables clockwise, until the question has been fully answered, one mark at a time.