



Basic Aerobic Exercise Physiology

Prof. Steven S. Saliterman
Department of Biomedical Engineering, University of Minnesota
<http://saliterman.umn.edu/>

Types of Exercise

- ▶ **Aerobic (Oxidative Phosphorylation)**
 - Any activity that uses **large muscle groups**, can be maintained continuously and is rhythmic in nature.
 - **Extracts energy** in the form of adenosine triphosphate (ATP) from amino acids, carbohydrates and fatty acids.
 - **Examples** includes cycling, dancing, hiking, skiing, jogging/long distance running, swimming and walking.
 - Product of the capacity of the **cardiorespiratory system** to supply oxygen and the **capacity of the skeletal muscles to utilize oxygen**.

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American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. USA: Lippincott Williams & Wilkins, 2013

Criterion for Aerobic Capacity

- ▶ Peak oxygen consumption (**VO₂Max**), which can be measured either through **graded exercise ergometry or treadmill** protocols with a oxygen consumption analyzer or via mathematical formulas.



Skiers, Sochi 2014 www.zastavki.com

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Patel, H., et al. "Aerobic Vs Anaerobic Exercise Training Effects on the Cardiovascular System." *World Journal of Cardiology*, no. 2 (Feb 2017): 134-38.

Types of Exercise...

- ▶ **Anaerobic (Glycolytic)**
 - Intense physical activity of very short duration, fueled by the energy sources within the contracting muscles and independent of the use of inhaled oxygen as an energy source.*
 - Without the use of oxygen, our cells revert to the formation of **ATP via glycolysis and fermentation**. This process produces significantly less ATP than its aerobic counterpart and leads to the build-up of **lactic acid**.
 - There is beneficially an increase in **C-type natriuretic peptide (CNP)**.
 - Synthesized in endothelium with protective effects on vasculature.
 - Prevents cardiac aging.

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*American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. USA: Lippincott Williams & Wilkins, 2013

Benefits of all Exercise

- ▶ **Physical inactivity is estimated to cause 30% of ischemic heart disease.**
 - High level of *leisure time* physical activity has a **beneficial effect** on CV health by reducing the overall risk incidence of **CHD and stroke** among men and women by 20% to 30%.
 - Moderate level of *occupational* physical activity might reduce the risk of CVD by 10% to 20% .
 - Positive impact on **CV healing**.

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Li J, Siegrist J. Physical activity and risk of cardiovascular disease-- a meta-analysis of prospective cohort studies. Int J Environ Res Public Health 2012; 9: 391-407

Benefits

- ▶ The inherent advantages of physical exercise stem from an **increase in the cardiac output and an enhancement of the innate ability of muscles to extract and to utilize oxygen** from the blood.
- ▶ Reduction in **total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and triglycerides (TG)**.
- ▶ Increases **high density lipoprotein cholesterol (HDL-C)**.
- ▶ Decreased **adipose tissue** distribution.
- ▶ Increased **insulin sensitivity**.
- ▶ Decrease in **Diabetes Mellitus** incidence.
- ▶ Improved **cognitive function**.
- ▶ Enhanced response to **psychosocial stressors**.
- ▶ Determent of **depression**.

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How much exercise?

1 to 2.4 h of exercise divided over 2 to 3 times per week, is the optimal quantity and frequency standard of aerobic exercise to promote improved health.

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Schnohr P, et al. Dose of jogging and long-term mortality: the Copenhagen City Heart Study. *J Am Coll Cardiol* 2015; 65: 411-419 [PMID: 25660917 DOI: 10.1016/j.jacc.2014.11.023]

What happens metabolically?

- ▶ Initially, small amounts of **ATP & creatine kinase** that are stored near the muscles cells, are available for use.
- ▶ However, within seconds of exercise **ATP** is depleted, and must be synthesized by either **oxidative** or **glycolytic** pathways.



Runners, London 2012
www.ebnation.com

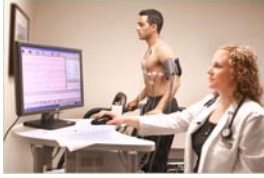
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Exercise Testing

- ▶ To determine **fitness**, an index of human performance, by measuring maximal oxygen consumption: **VO₂max**
- ▶ To understand how exercise relates to health and disease – i.e. aging, heart failure, arrhythmias, and hypertension.
- ▶ To discover and follow underlying coronary artery disease (typically without ventilatory gas exchange analysis) and risk assessment.

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How do we test?



NovaMed Diagnostics, Inc.



Treadmill, Bicycle and Arm Ergometers

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Ventilatory Gas Exchange Analysis...

- ▶ Room air is **inhaled** through the valve, and air which is **exhaled** goes through a tube into a metabolic measurement cart.
- ▶ Instruments measure the **amount of oxygen and carbon dioxide, and volume of air exhaled.**
- ▶ It is then possible to determine the amount of oxygen consumed.



GRECC, VA Medical Center

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Measuring VO_2

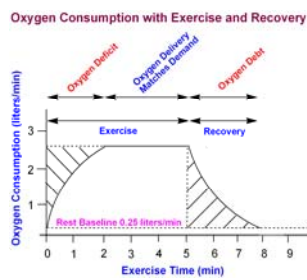
- ▶ Whole-body oxygen consumption is measured by analyzing the air breathed - or "pulmonary gas exchange."
- ▶ VO_2 is the difference between inspired and expired volumes of oxygen:
 - $VO_2 = V_I O_{2I} - V_E O_{2E}$ (*"i" is inspired, and "e" is expired*)
 - Where $V_I O_{2I} = V_I \times F_{iO_2}$ and $V_E O_{2E} = V_E \times F_{eO_2}$
 - $VO_2 = (V_I \times F_{iO_2}) - (V_E \times F_{eO_2})$, and for normal air,
 - $VO_2 = (V_I \times .2093) - (V_E \times F_{eO_2})$

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- ▶ So, we need to measure the following:
 1. V_i , the total volume of air inspired
 2. V_e , the total volume of air expired during the same period and
 3. F_eO_2 , percent or fraction of oxygen in the air breathed out.
- ▶ The assumption is that oxygen in normal air is a constant 0.2093. In practice we correct VO_2 and VCO_2 values for STPD conditions (standard temperature, pressure and dry)

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Oxygen Consumption



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Maximal O_2 Consumption (VO_{2max})

- ▶ May be expressed as:
 - Liters O_2 /min or
 - O_2 /(kg x min), to adjust for weight.
- ▶ The three major determinants are:
 1. **Cardiac output** (heart rate x stroke volume).
 2. **Oxygen** carrying capacity of blood (hemoglobin).
 3. Amount of exercising **muscle** and ability to utilize oxygen (more mass and more Type 1 fibers, more consumption).

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- ▶ **VO₂max** is the point at which there is *no further increase in oxygen uptake despite further increases in workload*.
 - Subsequent increased workload is possible because energy is produced by **anaerobic** metabolism. There will be a buildup of lactate.

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- ▶ **VO₂max** is also an *indicator of the system's ability to deliver oxygen to active muscles*.
 - It may be twice as high in a trained individual because of increased stroke volume, improved myocardial function, and a higher capacity of oxidative metabolism in active muscles.
 - Healthy individuals have an average **VO₂max** of **38 mL/kg** in woman and **44 mL/kg** in men.
 - Increases in **VO₂max** have been related to reduction in death from all causes.

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Cardiac Output

- ▶ **Cardiac output** at rest is about 5 liters/minute.
- ▶ In an untrained individual **heart rate** is about 72 beats per minute & **stroke volume** is 70 ml.
- ▶ **Maximal HR** are related to age and appear to be unrelated to the level of fitness.
- ▶ **Stroke volume** also typically increases with exercise, and **maximal cardiac output** in highly trained individuals may attain 40 L/min.
- ▶ The ability to generate high **maximal cardiac output** is a major determinant of the ability to have a high **VO₂max**.

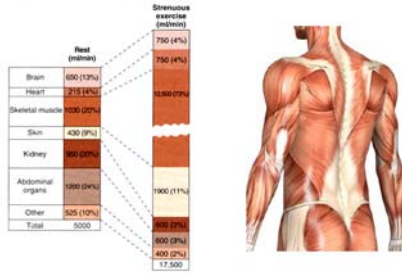
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Oxygen Delivery to Tissues

- ▶ The ability of tissues to take oxygen from the blood is referred to as **extraction of oxygen**.
- ▶ **Red blood cells** are required for oxygen delivery.
- ▶ The larger the **mass of exercising skeletal muscle** the greater the potential for increasing whole body oxygen consumption (remember the number of muscle fibers does not change).
- ▶ Also, the manner in which the **skeletal muscle has been trained** and the **muscle fiber type** will influence the ability of the muscle to extract oxygen.

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Redistribution of Blood Flow...



Vander, A; Human Physiology, 2001

www.backinaction.com

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Summary

- ▶ The inherent advantages of physical exercise stem from an increase in the **cardiac output** and an enhancement of the innate **ability of muscles to extract and to utilize oxygen** from the blood.
- ▶ **VO₂**, or oxygen consumption is the difference between inspired and expired volumes of oxygen.
- ▶ Three major determinants (**VO₂max**) are:
 1. Cardiac output.
 2. Oxygen carrying capacity of blood.
 3. Amount of exercising muscle and ability to utilize oxygen.
- ▶ 1 to 2.4 h of exercise divided, over 2 to 3 times per week, is the optimal quantity and frequency standard of aerobic exercise to promote improved health.

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