



Ashley Wagner, Sochi 2014 www.gotceleb.com

Basic Aerobic Exercise Physiology

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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**.

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

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.

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**.

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.

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.

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.

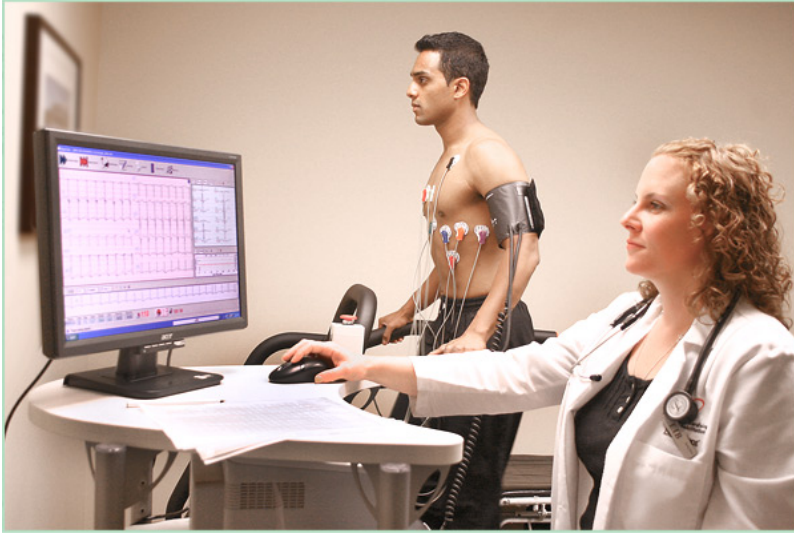


Runners, London 2012
www.sbnation.com

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.

How do we test?



NovaMed Diagnostics, Inc.



Treadmill, Bicycle and Arm Ergometers

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 measures 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

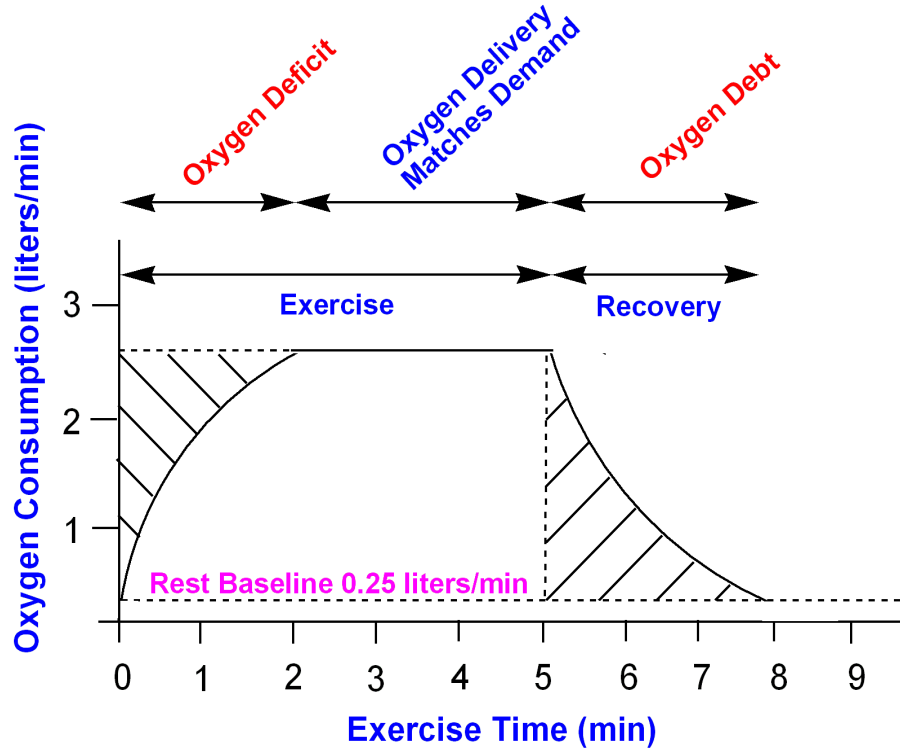
Measuring $\dot{V}O_2$

- ▶ Whole-body oxygen consumption is measured by analyzing the air breathed – or “pulmonary gas exchange.”
- ▶ $\dot{V}O_2$ is the difference between inspired and expired volumes of oxygen:
 - $\dot{V}O_2 = V_i O_2 - V_e O_2$ (*“i” is inspired, and “e” is expired*)
 - Where $V_i O_2 = V_i \times F_i O_2$ and $V_e O_2 = V_e \times F_e O_2$
 - $\dot{V}O_2 = (V_i \times F_i O_2) - (V_e \times F_e O_2)$, and for normal air,
 - $\dot{V}O_2 = (V_i \times .2093) - (V_e \times F_e O_2)$

- ▶ 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)

Oxygen Consumption

Oxygen Consumption with Exercise and Recovery



Maximal O₂ Consumption (VO₂max)

- ▶ May be expressed as:
 - Liters O₂/min or
 - O₂/(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).

- ▶ **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.

- ▶ **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.

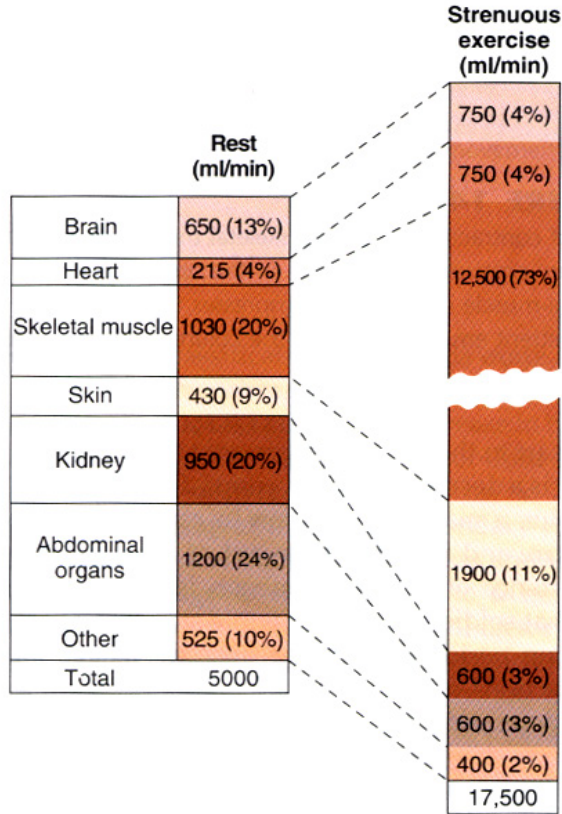
Cardiac Output

- ▶ **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**.

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.

Redistribution of Blood Flow...



Vander, A; Human Physiology, 2001

www.backinaction.com

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.
- ▶ VO_2 , or oxygen consumption is the difference between inspired and expired volumes of oxygen.
- ▶ Three major determinants (**VO_2max**) 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.