Physiology Labs Protocols

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Labs aim: Explore biology in context through brain and hands

Exercise physiology

Exercise physiology focuses on the functional changes of the body during the physical activity. Reaction (immediate changes and adjustments of the body) and adaptation (short-term to long-term adjustments of the body, e.g., induced by training) to physical activity depends on the type, intensity, duration, and frequency of exercising.

For the body to be able to carry out a certain movement or to carry out a more complex physical activity, it is necessary that the corresponding systems mediating or controlling such activity start working more intensively. Muscles that contract by utilizing energy are especially important for generating physical activity. Muscle work can easily be quantified and measured in the form of mechanical energy, or mechanical power, since the muscle contraction generates the force that is acting over the distance which, from the physical point of view, corresponds to energy.

The power of the long-term mechanical work generated by muscles, or say the mechanical output of exercising individuals, is mainly limited by O_2 supply to the muscles. In case muscles are contracting anaerobically, then the actual O_2 consumption in muscles is not a major factor determining their activity, and the limiting factor of muscle work (more precisely of muscle strength) becomes the mass of muscles. Duration of the anaerobic maximal activity is limited by the actual intracellular storage of substrates releasing immediate energy for contraction (macroergic compounds like phosphagens and ATP), and also by the ability to remove anaerobic metabolic waste from contracting myocytes, limiting the maximal muscle performance to a few seconds, or tens of seconds in case the energy is obtained from anaerobic glycolysis.

For long-lasting exercising, however, the most limiting factor determining the mechanical power of our muscles is the ability of the cardiovascular system to deliver a sufficient amount of O_2 into working muscles (endurance training increases the efficiency of aerobic exercise mainly by increasing the aerobic capacity of the heart, as well as by increasing the number of mitochondria in muscle cells). That ability is best correlating with the cardiac output which is the most important parameter determining the maximal level of any aerobic metabolism. It is obvious that changes in the heart rate and stroke volume would thus play a very important role in delivering an adequate O2 supply, which obviously would not be accomplished without adequate changes in the respiratory system (increased minute ventilation), and without corresponding changes in the peripheral circulation (dilation of muscle arterioles).

Principles of the lab:
The best way to investigate and quantify how examined parameters change with the increasing level of exercise is to vary the mechanical power (mechanical output, expressed in wats) of the tested exercising individual in a controlled way. On cycloergometer, this is accomplished by adjusting the resistance of pedals during the cycling (the higher the resistance the bigger is the resulting mechanical work of exercising subject). However, the mechanical power of a pedaling subject is dependent also on the cycling frequency (expressed as Rotations Per Minute – RPM), which should be kept constant at the desired level to comply with constant mechanical power. Sticking to an exact RPM during the exercise is however far from an easy task, but making the resistance inversely proportional to the actual RPM makes the mechanical power of exercising subject by principle constant. Therefore, once you set up the requested value of mechanical power for a tested individual on the cycloergometer display, the device is automatically changing the pedal resistance, keeping the resulting mechanical power of the cycling subject at desired values, provided the value of RPM is within 30 – 90. Similar principles work on treadmills, whose slope and speed of the belt could be preset to impose or enforce the requested mechanical power.

AIMS of the lab:
Understanding reactions of our body to physical exercise by focusing on the cardiovascular system, respiratory system, and metabolic rate during various levels of physical exercise (1. level 0.5W/kg, 2. level 1 W/kg, 3. level 1.5 W/kg, 4. level 2W/kg, each exercise period lasts 4 min). The following parameters will be measured right after the end of each exercise level during the measurement period which should not be longer than 1 minute:

- **heart rate**
  - can be measured continuously by pulse oximetry
  - by ECG (station 2 equipped with the ECG machine)
- **minute ventilation** (station 1 equipped with the matabolimeter which is working together with the spirometer)
- recording of **ECG** at the end of each level of exercise, comparing ECG waves and intervals recorded in various levels of exercise
- **blood pressure measurement** with the undirect method at both stations

After the last, the highest exercise level, the recovery of observed parameters towards resting values should be observed over the subsequent 10 min during which the abovementioned parameters will be monitored.

REQUIRED KNOWLEDGE

- **Parameters of cardiovascular system** at rest and during maximal exercise: cardiac output, heart rate, systolic pressure, diastolic pressure, stroke volume, ejection fraction
- **Parameters of respiratory system** at rest and during maximal exercise: minute ventilation, respiratory rate, tidal volume, SpO_2, $EtCO_2$, static and dynamic lung parameters (volumes)
- **Parameters related to metabolism** at rest and during maximal exercise: metabolic rate, minute O_2 consumption, CO_2 production, heat production,

exercise (muscle work) efficiency (the ratio of mechanical work rate over energy expenditure)

- **Parameters of the blood** at rest and during maximal exercise: ***venous vs. arterial blood*:** Hb saturation, partial pressure of O_2 and CO_2, blood flow through the muscles (global vs. local), principles of diffusion of O_2, the role of Bohr effect in O_2 delivery into tissues
- **Differences between aerobic vs. anaerobic metabolization**: lactic acid levels in the blood, pH, oxygen debt, limits of mechanical power
- **Thermoregulation:** mechanisms of temperature regulation, ways of heat dissipations, perfusion of the skin and muscles

TASKS

Observation and measurement of selected parameters of cardiovascular system, respiratory system, and metabolic rate during various levels of exercising at 2 measuring stations:

Station 1 equipped with the **cycloergometer, metabolimeter, and undirect blood pressure measurement**

Station 2 equipped with the **cycloergometer, ECG, and undirect blood pressure measurement**

1) Measure resting values at each station before the exercise starts
2) Commence the first exercise level at 0.5W/kg (set up the desired value of physical power at 0.5W/kg on the display of the ergometer). Let the subject cycle on the pedals with roughly 60 RMP over 4 minutes.
3) Measure the abovementioned parameters right after the exercise period is over. This measurement period should not be longer than 1 minute.
4) Increase the power of physical exercise by 0.5 W/kg. Commence the next 4 min. period of exercising.
5) Repeat tasks 3) and 4) till the level of mechanical power of the exercising subject is 2W/kg.
6) Measure the abovementioned parameter over the subsequent 10 min. till they return to resting ranges.
7) Analyze and discuss the collected data

QUESTIONS

1. How much can the actual metabolic rate be increased from resting condition to maximal exercising (consider aerobic as well as anaerobic muscle work)
2. Does the O_2 consumption increase linearly with the actual metabolic rate during exercising?
3. What is the efficiency of the generation of mechanical power by muscles? (the ratio of mechanical work rate over energy expenditure rate)
4. Cardiac output can be increased 5-6 times whereas the O_2 consumption 15-20 times. How is this statement compatible with the fact that all O_2 is delivered into tissue by perfusion?
5. How much of the heat is released during the exercise in which the mechanical power of the exercising subject is maintained at 200W?
6. Under which condition does the actual metabolic rate equal the heat release rate out of the body?
7. How much O_2 can the 1 liter of blood give off to the tissues?