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Lecture No. 1
Lecture Title: General Effects of Systematic Exercise on Respiratory System and Cardiovascular System

Introduction

Response of the Respiratory System to Exercise

Consisting of a series of body parts including the lungs, diaphragm and nasal cavity, the respiratory system is responsible for transporting oxygen and carbon dioxide to and from muscles and tissues. During exercise, the respiratory system increases to meet the demands of the working muscles. The respiratory system also uses the cardiovascular system -- heart, blood and blood vessels -- to transport oxygen and carbon dioxide.

Heart Rate

During exercise, your adrenal gland increases production of adrenaline and noradrenaline that directly affect the heart and the ability to transport oxygen and carbon dioxide throughout the body. The hormones then directly influence the sympathetic nerves to stimulate the heart to beat stronger for increased stroke volume and faster for increased heart rate and an overall increase in cardiac output.

Oxygen Transport

To meet the increasing oxygen demands from the working muscles, additional oxygen must be transported through the blood vessels. During exercise, the sympathetic nerve stimulates the veins to constrict to return more blood to the heart. This blood is carrying carbon dioxide from the muscles and can increase the total stroke volume of the heart by 30 to 40 percent.

Respiratory Rate

With an increased amount of oxygen and carbon dioxide transport, your respiratory rate -- rate of breathing -- also increases. This increase is also influenced by the sympathetic nerves stimulating the respiratory muscles to increase the rate of breathing. At rest, your respiratory rate is about 14 per minute but can increase to 32 per minute during exercise. The increased respiration rate allows more oxygen to reach the lungs and blood to be delivered to the muscles.

Long Term Response

A long-term respiratory system response to exercise involves several physiological adaptations. These adaptations ultimately result in an increase in overall efficiency of the respiratory system to gather, transport and deliver oxygen to the working muscles. The long-term respiratory function is commonly measured with a VO2 max test that calculates your body's ability for oxygen consumption during maximal exercise. Through exercise and training, the effectiveness of the respiratory system and VO2 max improve.

What are the Effects of Exercise on Human Respiratory System ?

Short-term effects of exercise

Would be increased use of oxygen (because muscles will require more oxygen in order to work) for heart to supply enough oxygen it has to increase its rate and stroke volume, so cardiac output will be high enough for all systems to get oxygen. Because body systems takes oxygen and gives carbon dioxide, lungs will have to work harder in order to remove carbon dioxide from blood and replace it with oxygen, so it will make breathing rate higher than normal.

Long-term effects of exercise

Would be increase capacity and effectiveness of lungs, faster gaseous exchange from carbon dioxide to oxygen. Body will be more efficient using oxygen.

Short term effects of exercise

In respiratory system would be increased breathing rate by about three times the normal rate, increased amount of air taken in or out with each breathe by five times the normal rate, increased blood supply to and through the lungs and increased

oxygen up take. Breathing rate returns to normal in 10 – 20 minutes being in rest mode.

Long term effects of exercise

For the lungs, you will have increased functional capacity during exercise, increased diffusion of respiratory gases (waste carbon dioxide exhaled from the body) and increased vital capacity (the maximum amount of air a person can expel from the lungs) which will decrease the debt of oxygen in blood while exercising. It also can prevent from lung disease and be more resistant to dust and mites. By exposing body to regular exercise (especially cardio exercises that includes running) you can increase cleaning process of lungs if you have been a smoker or working in dusty places.

A very important muscle for lungs is diaphragm which makes the air to be sucked in to the lungs. By exercising you increase the strength of diaphragm. Also increase in the number of capillaries that is surrounding the alveoli that makes the gaseous exchange process faster and more effective.

Exercise : Effects on the Respiratory System

Effects of physical activity and sports on the respiratory system mainly depend on changes in alveolar CO2 levels. Here, after analyzing basics of oxygen transport (changes in CO2 and O2 concentrations in the blood and cells), we are going to provide clear and simple answers to the following questions:
- What are the exact criteria that determine the long-term positive effects of exercise on overall health and well-being?
- Are these criteria different in healthy and sick people?
- If exercise is healthy, why do thousands of sick people die every year from coronary-artery spasms, anginas, infarcts, strokes, exercise-induced asthma attacks and many other acute exacerbations of diseases during or following physical exercise?
- Is graded exercise therapy useful for all patients?
- What is going on with the respiratory system of these people during exercise?
- What are the short-term and long-term effects of exercise on the respiratory system?

Table. MV (Minute Ventilation) and Rf (Respiratory Frequency) at rest

Condition	MV, L/min	Rf, breaths/min	Oxygen extraction, %	Breath pattern	References (click below for details)
Diseases*	12-18	>18	<12 %	Overbreathing	Over 40 studies
Healthy	6-7	10-12	25 %	Normal	Results of 14 studies
Norm	6	12	25 %	Normal	Medical textbooks
Super-health	2	3	>60 %	Ideal	Observations/yoga

***Chronic diseases include heart disease, diabetes, asthma, COPD, cystic fibrosis, cancer, and many others. Study Hyperventilation Syndrome for references and numbers.**

As it is easy to observe, heavy breathing at rest results in relatively heavy breathing during exercise and that makes moderate or intensive exercise in the sick very difficult or impossible.

Table. Minute ventilation during moderate exercise (15-fold metabolism)

Condition	Minute ventilation	Short-term respiratory effects	Blood lactate	Duration of performance
Chronic diseases	About 150 L/min	Maximum mouth	Very high	A few minutes

		ventilation		
Normal breathing	90 L/min	Heavy nose breathing	Elevated	1-2 hours
Super health states	30 L/min	Easy nose breathing	Nearly normal	Many hours

If you attend a typical mass running event or open marathon, you will notice numerous ambulances with paramedics, who are ready to provide rescue help and **oxygen**, regardless of the details of the chronic disease (heart disease, stroke, seizures, exercise-induced asthma, and so forth). Whatever the condition, *low brain and heart oxygen levels* are most likely physiological causes of possible deaths. Hence, the main questions then are: What are the factors that define effects of exercise on the respiratory system? What is going on with blood gases or O2 and CO2 in the blood and body cells? The answers depend on the pre-existing respiratory parameters and levels of blood gases before and after exercise.

Exercise and the Respiratory System in Healthy People

Consider the short-term effects of exercise in healthy people. Textbooks on exercise physiology suggest that, in fit and healthy people, arterial CO2 levels rise slightly with light, moderate, medium and sub-maximum exercise intensity levels regardless of the route of breathing during exercise (mouth or nasal or combined). Since CO2 is the powerful vasodilation agent, expanded arteries and arterioles improve blood and O2 delivery to all vital organs of the human body, including the heart and brain. Vasodilation ensures aerobic respiration in body cells making it possible for healthy people to enjoy all the benefits of aerobic exercise without any major problems related to tissue hypoxia causing excessive blood lactate, muscle spasms, injuries, low recovery rates, overexcitement, stress, poor sleep later, etc.

Hence, healthy people experience immediate positive effects of exercise on the respiratory system and blood gases. What happens after exercise (long-term effects of exercise on the respiratory system)? Since breathing is controlled by CO2, the usual exercise effects for fit and healthy people are simple: **breathing after exercise becomes lighter and slower due to an adaptation of the respiratory system and the breathing centre to higher CO2 levels**. As a result, the body-oxygen content increases for many hours after the exercise. This especially relates to the next-morning body oxygenation, and this is the main criterion of exercise

efficiency, if someone decides to measure the exact long-term effects of exercise on the respiratory system.

However, when very healthy and healthy people do exercise with strictly nasal breathing, their blood gases during exercise are different in comparison with mouth breathing. Arterial CO2 gets even higher, and arterial oxygen saturation becomes slightly less in a dose-dependent manner. Nasal breathing (in and out) slightly worsens the immediate performance and results, but is incomparably better in the long run. Why? **Intermittent hypoxic hypercapnic training**, as in case of nose breathing (in and out), is an excellent way to improve VO2 max, body-oxygen content and achieve adaptation of the breathing centre to higher CO2.

VO2max (definition)= the maximal oxygen uptake or the maximum volume of oxygen that can be utilized by the human body in one minute during maximal exercise. It is measured as milliliters of oxygen used in one minute per kilogram of body weight (ml/kg/min). VO2max is usually ranged from 20-40 ml/kg/min (in unfit and ordinary subjects) and up to 80-90 ml/mg/min (in elite endurance athletes). Physiologically, it is the most significant parameter that predicts long-term endurance and performance in athletes.

One can try both these approaches (reduced nasal breathing on some days and heavy mouth breathing in others) and compare the effects of both types of exercise on your well-being. It is, for example, easy to discover that physical exercise with strictly nose breathing significantly reduces pulse for the same intensity level for any particular individual in comparison with mouth or combined breathing. Hence, the positive effects of physical exercise with nasal breathing only are immediate. They can be easily measured with sport watches and other devices that can record heart rate during exercise.

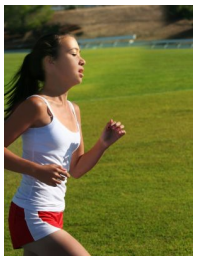
Exercise and the respiratory system in sick people

Sick people have heavy and deep breathing at rest before exercise. Hence, their have abnormal blood gases prior to exercise. Usually they suffer from arterial

hypocapnia (low CO2 due to overbreathing) and (likely) mild arterial hypoxia, if they are chest breathers. (Chest breathing, as we discussed, reduces oxygen level in the arterial blood.)

If they have problems with their lungs or ventilation-perfusion mismatch (as in a small group of patients with severe asthma, bronchitis, or emphysema), their arterial CO2 is too high (up to 50-60 mm Hg), but blood oxygenation is low already at rest, causing dyspnea (shortness of breath sensation) even during low intensity exercise.

Overbreathing at rest reduces their body-oxygen levels. As a result, many people with diabetes, cancer, heart disease, chronic fatigue and many other conditions have elevated blood lactate level at rest, indicating the presence of cell hypoxia and anaerobic cellular respiration. Mild exercise generates even more lactic acid due to initial oxygen deficiency. (This is the common reason why the sick people do not like exercise.) As a result, since the lactic acid level is also controlled by the respiratory system, the body starts to remove bicarbonates (CO2) from the blood by increased ventilation (metabolic acidosis). To maintain blood pH in the normal range, the breathing centre intensifies minute ventilation to remove some CO2 from the body. The breathing becomes disproportionally heavier (the main short-term effect of exercise in the sick). This is possible to observe in many sick people during exercise: heavy panting, usually through the wide open mouth.



Mouth breathing, as we've previously discussed, further reduces the arterial and cellular CO2, creating brain hypoxia and increasing heart rate. Nasal breathing, on the other hand, prevents CO2 and nasal NO (nitric oxide) losses and improves brain and heart-oxygen content provided that the intensity of exercise matches oxygen delivery.

The overbreathing caused by mouth breathing during exercise can continue for many hours after exercise, if it is too intensive or anaerobic. Exercise with low intensities are better tolerated, but mouth breathing still negates any improvements in heart and body oxygen level canceling positive long-term effects of exercise on the respiratory system. It is normal then that severely-sick individuals can easily die due to moderate or intensive exercise combined with other hyperventilation-inducing lifestyle factors, including stress, overheating, overeating before the exercise, drop in blood glucose level, chest breathing, etc. It is not a surprise then that graded exercise therapy has conflicting results so far.

There are many coaches and fitness instructors these days who teach their athletes, students, and pupils to breathe in through the nose and out through the mouth in order to improve long-term effects of exercise on the respiratory system. This breathing technique for physical exercise is half-better than mouth breathing due to improved absorption of nitric oxide and some increase in arterial CO2.

Conclusion

The effects of exercise on the respiratory system and body-oxygen content in the sick are generally negative due to mouth breathing. There are, however, some positive effects of exercise due to perspiration, shaking of the body, stimulation of the respiratory muscles and lungs, production of endorphins, and others.