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Lecture Title : The Cardio – Respiratory System and Exercise - II

Introduction

Aerobic training typically produces an increase in functional capacities related to oxygen transport and use in the body. Aerobic endurance training produces significant increases in maximal oxygen consumption (VO2max). Maximal oxygen consumption is an indicator of the level of cardiovascular, pulmonary, and neuromuscular function.

Cardiovascular adaptations to aerobic training include cardiac hypertrophy. This is characterized by an increase in the size of the left ventricular cavity and a modest increase in wall thickness. An increase in total blood volume may contribute to cardiac hypertrophy.

Regular training results in increased cardiac output during subsequent exercise resulting in improved delivery of oxygen to active muscle. Increased end diastolic volume as well as an increase in myocardial contractility result in an increase in stroke volume during rest and exercise. At the same time, the resting and submaximal exercise heart rate actually decreases. The increase in cardiac output is a direct result of improved stroke volume.

Systolic and diastolic blood pressure during rest and submaximal exercise decreases with regular aerobic training.

Much of the improvement in pulmonary function in response to aerobic training is attributable to strengthened respiratory musculature. The respiratory musculature becomes more efficient reducing the oxygen costs attributable to breathing.

Strengthened respiratory muscles improve respiratory efficiency and minimizes respiratory work at a given exercise intensity. Trained athletes can maintain alveolar ventilation by increasing tidal volume with only a small increase in breathing rate. Trained athletes can also sustain a higher breathing rate if necessary.

Effects of Exercise

Exercise affects the circulatory system, respiratory system and the muscles. Short term effects occur immediately as we begin to exercise. Long term effects are more concerned with adaptive changes over time with regular exercise.

Short Term Effects of Exercise

When we begin to exercise the body has to respond to the change in activity level in order to maintain a constant internal environment (homeostasis). Here are the changes which must take place within the muscles, respiratory and circulatory system:

Circulatory System

- The release of adrenaline (often before exercise even begins) causes the heart rate to rise
- This increases Cardiac Output
- Venous return increases due to the higher Cardiac Output and the skeletal muscle pump and respiratory pump
- Increases in Lactic Acid (produced during the early anaerobic phase of exercise), Carbon Dioxide (due to increased rates of energy production) and temperature all act as stimuli to the cardiac control centre which responds by further increasing the heart rate
- Oxygen levels within the blood decrease which causes increased diffusion at the lungs
- Blood pressure increases, thus increasing flow rate and the speed of delivery of O2 and nutrients to the working muscles
- Vasodilation and vasoconstriction ensure blood is directed to areas that need it (muscles, lungs, heart) and away from inactive organs

Respiratory System

- Changes in the concentration of CO_2 and O_2 in the blood are detected by the respiratory centre which increases the rate of breathing
- The intercostal muscles, diaphragm and other muscle which aid the expansion of the thoracic cavity work harder to further increase the expansion during inhalation, to draw in more air.

Muscles

- The higher rate of muscle contraction depletes energy stores and so stimulates a higher rate of energy metabolim.
- The bodys energy stores are slowly depleted
- Myoglobin releases its stored Oxygen to use in aerobic respiration. O_2 can now be diffused into the muscle from the capillaries more quickly due to the decreased O_2 concentration in the muscle.

Long Term Effects of Exercise

Regular exercise results in adaptations to the circulatory, respiratory and muscular systems in order to help them perform better under additional stress. Here are the changes which must take place within the muscles, respiratory system and circulatory system:

Circulatory System

- The cardiac muscle surrounding the heart hypertrophies, resulting in thicker, stronger walls and therefore increases in heart volumes. The more blood pumped around the body per minute, the faster Oxygen is delivered to the working muscles.
- The number of red blood cells increases, improving the bodies ability to transport Oxygen to the muscles for aerobic energy production.
- The density of the capillary beds in the muscles and surrounding the heart and lungs increases as more branches develop. This allows more efficient gaseous exchange of Oxygen and Carbon Dioxide.

- The resting heart rate decreases in trained individuals due to the more efficient circulatory system.
- The accumulation of lactic acid is much lower during high-levels activity, due to the circulatory system providing more Oxygen and removing waste products faster.
- Arterial walls become more elastic which allows greater tolerance of changes in blood pressure.

Respiratory System and Exercise

- The respiratory muscles (Diaphragm/intercostals) increase in strength.
- This results in larger respiratory volumes, which allows more Oxygen to be diffused into the blood flow (VO2 max)
- An increase in the number and diameter of capillaries surrounding the alveoli leads to an increase in the efficiency of gaseous exchange.

Muscle

- Increased numbers of mitochondria (the cells powerhouse) means an increase in the rate of energy production.
- The muscles, bones and ligaments become stronger to cope with the additional stresses and impact put through them.
- The amount of myoglobin within skeletal muscle increases, which allows more Oxygen to be stored within the muscle, and transported to the mitochondria.
- Muscles are capable of storing a larger amount of glycogen for energy.
- Enzymes involved in energy production become more concentrated and efficient to aid the speed of metabolism.

The effects of exercise on the cardiovascular and respiratory system Essay

The objective of this report is to critically explain the physiological effects of exercise on the human respiratory system and cardiovascular system. To begin with, I will explain the two systems, their specific functions and how they inter-relate. I will then go on to analyse the effects of exercise on the two systems by looking at the way in which the body deals with an increased workload, and any health issues that may affect this.

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Cardiovascular system

This system is responsible for pumping blood and oxygen around the body. It is a network made up of

blood vessels that transport carbon dioxide from the body to the lungs. The heart is an organ so needs a constant supply of oxygen. This is supplied by a separate network of blood vessels called the coronary system, made up of coronary veins and arteries. The heart is the size of a clenched fist, located slightly to the left of the chest. It is divided into left and right sides, has four chambers and works as a pump. Veins deliver deoxygenated blood from the body to the right side of the heart; this is known as Pulmonary Circulation. The heart then pumps this back to the lungs to absorb oxygen. Oxygenated blood returns to the left side of the heart which pumps it to the rest of the body through the arteries; this is known as Systemic Circulation. (Munford, K, 2012, cited in Bupa).

Respiratory System

This system is responsible for ensuring the body has a constant supply of oxygen, whilst removing carbon dioxide. It is made up of six organs and there are three major parts of the system; the airway, the lungs and the muscles of respiration. The respiratory system supplies the oxygen needed for the cardiac work load and its main function is gaseous exchange (Taylor, T cited in Inner Body).

Breathing volumes

Control of breathing by the medulla

Unlike the cardiovascular system which has myogenic cardiac muscle in the heart, the respiratory system is controlled by nerve signals from the brain. START: Impulses from the respiratory centre cause contraction of intercostal and diaphragm muscles which cause inspiration to start

Lungs inflate and air moves in:
Inspiration
Inflation of lungs stimulate stretch receptors in walls of bronchioles which fire off nerve impulses to the respiratory centre

At the end of expiration, the inhibition of the respiratory centre is removed. Stretch receptors are no longer stimulated so no more nerve impulses are fired off

Impulses from the stretch receptors begin to inhibit the respiratory centre

Inhibition of the respiratory centre prevents impulses causing inspiration; no impulses cause the muscle to relax so expiration occurs passively Lungs deflate and air moves out:

Expiration

As the lungs become more inflated, more impulses are sent to the respiratory centre and it is completely inhibited

Gas Exchange

Gas exchange happens in the alveoli and is the process of supplying the blood with oxygen and removing carbon dioxide; a waste product of cell respiration. Without gas exchange, oxygen would not get into the blood and there would be a build-up of carbon dioxide in the body. If these two things happened the body would not be able to function to stay alive. Gas exchange can happen because the concentration gradient across the alveoli wall is maintained by blood flow on one side and air flow on the other (IHW, 2006, Biology Mad).

Tissues found in the two systems

TissueType
CardiovascularSystem
RespiratorySystem
Connective Tissue

– Blood is a loose connective tissue transporting substances around the body – Outer layer of blood vessels are made up of loose connective tissue meaning they are soft and pliable enabling diffusion -Different cell arrangements are suspended in an extra cellular matrix forming the characteristics of tissue. The matrix is what makes the tissue strong and protects the cellts. It is made up of protein and carbohydrates

– The trachea and bronchi are both supported by C shaped rings of cartilidge to keep them open. The ring is not complete which means they can still move.

– The epiglottis is made out of cartilidge

– Connective tissue is found wherever there is epithelial tissue as it makes up the base membrane of epithelial tissue Epithelial Tissue

– Inner layer of blood vessels are made up of simple squamous epithelial tissue enabling blood to flow without friction and allowing diffusion

-Endocardial (inner) layer of heart is lined with simple endothelial tissue allowing blood to flow without friction; preventing damage to cells – The walls of the alveoli are made up of simple squamous epithelial tissue to allow quick diffusion – Pseudostratified ciliated epithelium line the upper respiratory tract to trap and move pollutants upwards with goblet cells producing mucus to trap debris. Ciliated cells sweep the mucus up out of the airways. Without this type of special lining tissue the lungs would get polluted with dirt from the air that is breathed in (Alberts, B et al, 2002)

Muscle Tissue

– The heart is made up of involuntary cardiac muscle meaning it contracts under control of the nervous system only – Myocardium (middle) layer of heart wall is cardiac muscle made up of myogenic cells enabling the heart to contract without nerve signals. This means the heart can carry on beating even if a person is classed as ‘brain dead’ – Muscle tissues are made up of specialised cells using energy to contract and create a pulling force (MVB, 2012)

– Smooth muscle is found in the bronchioles to control air flow into different portions of the lung. Due to the absence of supporting cartilidge and the size of the bronchioles, they are exposed to the possibility of collapsing and becoming blocked – (cited in Barts and The London School of Medicine and Dentistry) – Skeletal muscle and fibrous tissue is found in the diaphragm enabling it to contract and relax

Nervous Tissue

– Sino-Atrian node is made up of nervous tissue enabling it to send electrical currents to make the heart contract Nerve sensors in the muscles of the respiratory system receive impulses from the brain to control breathing. The brain detects oxygen/CO2 levels in the body so without this type of tissue, the respiratory system would not know when it needed to speed up or slow down (cited in National Heart, Lung and Blood Institute, 2014)

Cellular Respiration

Cellular respiration is a process in which the energy in glucose is turned into Adenosine Triphosphate (ATP). This is the energy cells need for the body to function. The cardiovascular and respiratory system both work together to aid this process by suppling the oxygen and glucose, and by removing carbon dioxide (gas exchange).

Cellular respiration occurs in one of two ways; aerobic and anaerobic respiration. Aerobic respiration occurs when there is a sufficent amount of oxygen in the cells. Glucose is broken down by oxygen; turning it into energy. Carbon dioxide and water are produced as waste products of this process. Glucose molecules carry a lot of energy as there are so many bonds and the energy that is released is stored as ATP. The equation for aerobic respiration is:

Anaerobic respiration occurs when aerobic respiration is unable to produce the amount of ATP energy needed because of lack of oxygen; usually during strenuous exercise. Anaerobic respiration happens without oxygen which means the glucose is only partially broken down making it inefficient. It also produces lactic acid which builds up and the muscles cramp, causing the person to stop exercising. Oxygen is needed to break the lactic acid down and this is referred to as oxygen debt. After anaerobic respiration a person will breathe heavily for a period of time to make up the oxygen and to return to aerobic respiration. The equation for anaerobic respiration is:

Without cellular respiration, the body would not receive the energy needed in order to function when at rest and when under pressure (cited in Biology Mad).

The effects of exercise on the two systems

When a person exercises, the body's demand for oxygen and energy increase. This means that both systems will be under stress and have to work harder in order to meet the need. The muscles in the heart and diaphragm will have to work quicker meaning they have less resting time. However as regular exercise would strengthen these muscles, this would result in larger breathing volumes, which in turn would allow more oxygen to be diffused into the blood flow. The heart muscles and walls would also get bigger and stronger meaning it can push more blood out per beat, so blood pressure would be lowered, even when at rest. It also improves the elasticity of the blood vessels meaning oxygen and glucose can be delivered at a faster rate to the muscles making the heart more efficient (Quinene, P cited in Live Strong, 2014). However, these muscles might not be strong enough to cope with the increased stress and should be built up over time. Exercise tolerance tests can determine an individual's safe level of exercise.

As the body demands more oxygen, the heart rate and pulmonary ventilation increase to supply the muscles with oxygen. Exercise temporarily increases the capillary density at the muscle site which makes gas exchange quicker and more efficient (Saltlin and Gollnick, 1983 cited in Gatorade Sports Science Institute).

However anaerobic respiration leads to oxygen debt and a built up of lactic acid, resulting in muscle cramp. It also limits the amount of energy the body receives, as the amount of ATP produced during anaerobic respiration is much lower than during aerobic respiration.

There are certain respiratory conditions that may limit an individual's ability to exercise, even if the cardiovascular system would benefit from more vigorous exercise. Conditions such as Asthma and Chronic Obstructive Pulmonary Disease (COPD) limit the amount of oxygen intake. Both of these conditions narrow the airways meaning the body cannot get the oxygen it needs. This in turn would cause the heart to pump harder to try and supply its need which would eventually fatigue the muscles (Kenny, T, 2014 cited in Patient).

A positive effect of exercise is that it can increase the 'good' cholesterol in the blood which helps to lower the 'bad' cholesterol. Over time, high cholesterol can cause blocked arteries which means that parts of the heart would be oxygen deprived. By lowering cholesterol you reduce the risk of blood clots and heart attacks as the blood can flow freely without obstruction (cited in WebMD, 2014).

One of the causes of Diabetes type 2 is obesity. It damages the blood vessels by narrowing and blocking them; which can cause strokes due to oxygen starvation in the brain. Exercise aids weight loss which in turn will reduce the risk of Diabetes type 2 (cited in NHS, 2012).

Conclusion

In conclusion it can be said that exercise is beneficial for both the cardiovascular and respiratory system as it helps to strengthen the heart and increases respiratory capacity. Even when underlying conditions are present, a safe level of exercise is recommended as it can help conditions from worsening. However, as the cardiovascular and respiratory system work together supplying the body with oxygen and energy and by removing carbon dioxide, if one system is unable to function properly under the stress of exercise, the other system will also suffer.