Introduction to Exercise Physiology & Sports Performance

Wg Cdr (Dr.) Chandrasekara Guru
Directorate of Medical Services

Lecture - 08
Cardiovascular System and Exercise - Part 1

Welcome back to this NPTEL course on introduction to exercise physiology and sports performance. You know wearable technology is one of the top fitness trends across the globe as per the American College of Sports Medicine survey conducted for the year 2023. You know all of us use these smartwatches, where you can have your heart rate recorded right. So how do you use this heart rate to the best of its benefit in terms of exercise training and improving your performance? So that is what we are going to deal with in this particular session. So, you might be having the question what should be the right heart rate training zone for my age, or for the activity that I do. Here, I am going to clear your queries with respect to heart rate. Welcome to this session on cardiovascular system and exercise.

So, this particular module will be divided into three parts. So I am Dr. Chandrashekara Guru. I am an Assistant Professor in Sports Medicine in the Armed Forces Medical Services.

What you will learn from this session: We know the basics of the cardiovascular system, various parameters, the determining factors, how these factors respond in terms of exercise; and how do we use to the best of the practice in terms of exercise training of these parameters. So the human body is a closed system. So it has a closed circulatory system, and the components of this closed circulatory system are the heart, which is the pump, and you have the blood vessel which is the pipe through which the blood is circulated. The components of the circulatory system are heart, blood vessels and blood. In this part 1, we will see in detail about these three components.

Why do you need a circulatory system? You have assumed it right. Circulatory system is basically to supply the food and oxygen to the cell, and carry back the waste products as well as the carbon dioxide from the tissues to the respective organs. Clear them off from the tissues. It also helps to maintain a body temperature, and also helps in fighting the disease. So, let us move on to the individual components.

We focus on the heart. The picture there shows you the location of the heart within the skeletal

framework. It is in the center of the chest, and it is a hollow structure which is just the size of your fist. Towards your left, and it is composed of specialized muscle or tissue called as cardiac muscle, and it is enclosed in a sac called pericardium. So, if you see the heart per se, it is divided into three layers: the outer pericardium, the middle myocardium and the inner endocardium. So you go from inside out; endocardium, myocardium and pericardium. The myocardium is the specialized cardiac muscle which acts as the pump, and it can contract.

As I mentioned the heart is a hollow chamber; so The heart is a hollow structure which is divided into various chambers. The chambers on top are called the atrium. The chambers on the bottom are called as the ventricles. These chambers are divided by means of septum. And the oxygenated blood in layman terms, it is pure blood.

And the deoxygenated blood or the impure blood, they don't mix up normally because of the presence of this septum. So let us see a cut section of a heart. So, you have cut open the heart to see the chambers of the heart. So let me explain here in the slide. So, this is the right side and this is the left side.

So if you see, if you notice the heart on the right hand side; you have the right atrium on top and the right ventricle at the bottom; and on the left hand side if you see, you have the left atrium and the left ventricle. So the right and left are divided by this septum what you have here; so thus, the chambers of the heart, they don't mix up blood, and the right and the left they don't mix up blood to be specific, and they are divided by the septum. The importance of the septum is that, if the septum is defective, it may end up in mixing up of blood. That is an important thing that you need to remember. Coming on to the Endocardium. The endocardium, the innermost layer of the heart, has multiple valves which only allow unidirectional blood flow.

That is, the blood can flow in only one single direction. So that between the right and the left if you see the right atrium is here. The blood from the right atrium enters into the right ventricle by means of what you called as the tricuspid valve. Why is the name: because it has three cusps that is the name tricuspid. We come to the left hand side, you have the left atrium and the left ventricle, the blood from the left atrium enters the left ventricle by means of mitral valve. The blood from the right ventricle is pushed into the pulmonary artery through this valve, called as pulmonary valve. Similarly, the blood from the left ventricle is pushed into the aorta. This is the aorta, and this is the valve, which is called as the aortic valve.

So, these are the different valves which control the movement of the blood. What is the importance? The timely closing and opening of the valves produces sounds. Commonly called as lub dub. So that is the heart sound.

S1 and S2. Heart sound 1 and Heart sound 2. In certain cases, there may be continuous

occurrences of additional sounds, so these are called as murmurs, because of some defects in the valves. So the entire gamut is termed as valvular heart disease. Moving further, how does the blood flow? Let us focus on the deoxygenated blood. So, if you see here, from the various parts of the body, the blood enters through two major veins: they are the superior vena cava, and the inferior vena cava. The blood from the lower body; that is the legs and the trunk enters through the inferior vena cava, and the blood from the head and neck and the upper limb enters through the superior vena cava, and empties in the right atrium. So, this deoxygenated blood further passes, if you follow the arrow mark, it passes through the tricuspid valve into the right ventricle. From the right ventricle, further when the heart contracts, if you notice the animation, when the heart contracts, it pushes the blood as the, see the pulmonary valve opening, through that it enters into the pulmonary artery, and from the pulmonary artery it is sent to the lungs. So, the deoxygenated blood which is high in carbon dioxide and low in oxygen is kind of pushed through the pulmonary artery into the lungs.

Lungs is the place where the respiration happens; wherein you inhale oxygen and this oxygen which you inhale gets you know pushed into the deoxygenated blood; and carbon dioxide is released out. So this is how the process of movement happens with respect to the deoxygenated blood. Let us proceed with the left side; What happens with the oxygenated blood? So, the deoxygenated blood reaches the lungs . The diffusion of these gases happens, and finally the oxygen enters the blood and this oxygenated blood enters from the lungs to the left side, left atrium by pulmonary veins. The pulmonary veins carry the oxygenated blood and drain into the left atrium, and from the left atrium through the mitral valve, the blood enters the left ventricle. When the heart contracts, and you see the aortic valve opening, the blood which is filled in the left ventricle is pumped into the aorta. I am so sorry, this goes through the aorta. The aorta is the red one, which is depicted here, so this is pumped out with a certain amount of pressure so that the blood that is being pumped from the left ventricle reaches even till the tips of your extremities. So, there has to be some amount of pressure for the flow of the blood to the you know, terminal most part of the body or the tissue. So, that happens from the left ventricle of the heart. Moving further, the heart has specialized tissue which I had mentioned before that is your conductive system formed within the cardiac muscle.

Say here, if you see in this animation, you will find that specified structures which are here marked in yellow. So, these are nothing but named as a sinoatrial node, which is present somewhere in the right atrium, and it itself generates the impulse activity of the heart. So the specialized tissue results in an electrical effect, which gets converted to form a mechanical contraction. So it is generated at a rate of 100 beats per minute at the level of the sinoatrial node. Further from there, the same is conducted through the atrioventricular node or the AV node.

You see here, it is located at the junction of the atrium and the ventricle of the right side. So it is called as the AV node, and from there it is further transmitted through the Purkinje fibers, which

again gets distributed throughout the muscles of the heart. So thus, through the system of SA node, AV node and Purkinje fibers, the electrical impulses are transmitted, which gets converted into a mechanical contraction, relaxation and the contraction of the heart. So, this particular electrical activity which is produced by the heart is what you record in your what you call as ECG or the electrocardiography. And in case of any abnormality in terms of electrical conductivity, you will end up in something called as arrhythmia, wherein; you will have different findings, abnormal findings, pathological findings. Moving further, let us focus on the second component, that is the blood vessel. So, the blood vessel is divided into three parts, it is a network of you know pipeline you can say, wherein the blood is distributed across the body as the heart pumps the blood. So the heart left ventricle pumps the blood into the largest artery of the body, that is the aorta, and from the aorta, the artery is further divided into multiple small branches across the tissue. It is just a schematic diagram, which is shown here and these particular arteries are further divided into smaller network of arteries, called as arterioles, and further inside the tissue you see the cells here.

So, inside the tissues further branching happens, and forms a single walled, you know single cell layered wall of blood vessels called as capillaries. So, through the capillaries, the diffusion happens in the tissue, and thereafter it continues to form the venules and the vein. So, from the left heart you have the oxygenated blood entering through artery, arterioles into the tissues through capillaries, and thereafter from the tissues the waste products are carried through the capillaries, venules and then the vein, then followed by the superior and the inferior vena cava into the right side of the heart. Know something in detail about each of these. Arteries are large blood vessels, as I had mentioned, and they have about 13% of the blood at any point of time during rest.

And they carry the oxygenated blood from the heart to various parts of the body. Since as I had mentioned before, they act against a certain amount of pressure at which the left ventricle or the heart pumps out the blood, their valves are slightly thicker, so that they can offer that resistance to the pressure that is generated by the heart. So their valves are slightly thicker. And can you guess an artery which is a misnomer where it carries a deoxygenated blood. If you have Given keen attention, you could have guessed the answer by now.

Yes, that is the pulmonary artery. So, we saw that the deoxygenated blood which enters the right side of the heart, the right ventricle, and then it is pumped into the pulmonary artery towards the lungs. So pulmonary artery is a misnomer. So pulmonary artery is the name, but then it carries a deoxygenated blood.

Let us focus on the capillaries. Capillaries are smallest blood vessels, which are layered by single cell. You know, it is mainly because of the easy exchange that is permeable through the cell in the tissue level. So, it helps in exchange of various nutrients, the gases. You know, across the cell wall, and it is at the level of the tissues, and then there is the remaining amount of blood, which

is located in the heart and lungs as well. So you have 7% of the blood in the heart, and 9% of the blood in the lungs. The last component of the blood vessel is the vein. And it is one of the important components.

You know why? Because, the maximum amount of blood resides in the veins of the system. Almost 64%, and they carry the blood from various parts of the body to the heart and the deoxygenated blood that is carried you know these veins have walls which are not so much thick as compared to the arteries; because the pressure comes down as it goes towards the vein in order to avoid that backflow. Because of the lower pressure, you also have certain additional you know, additional valves within the veins so that when once the contraction happens, when the blood flows then the valve closes and prevents the backflow. This is especially important since we are erect and our movement of the deoxygenated blood towards the heart happens from the extremities towards the heart. Heart is at a higher location, you know, so it has to go against gravity.

So, in order to avoid the backflow because of the gravity, you have more valves located in the lower limb veins. Further, you also have these veins co-located along the muscles. As soon when the muscle you know contracts, that also helps in pumping of this blood towards the heart, so that is why you would have heard about peripheral pump. The peripheral pump is nothing but your calf muscle of the legs, which is also called as peripheral pump. The central pump is nothing but your heart, and the peripheral pump that is a muscle. Since the veins are co-located along the muscles or through the muscles, the contraction of this results in pumping of this blood towards the heart, right side of the heart. So that is why the calf muscles are called as the peripheral pump. And you know what happens when the valves which are located in the veins fail? It ends up in a clinical condition.

I will give you a clue. You can guess it. I have shown a traffic signal also there. Because of prolonged activity it can happen. Yeah, if you have guessed it right, yes, it is more common in traffic policemen because of their long duration standing hours, and the condition is called as varicose veins, common in the lower limbs.

So, we are covering the last component of the circulatory system, that is the blood. The blood has two parts, the plasma and the blood cells. The plasma forms the liquid component, with 90% of it being water, and 10% of it is the remaining nutrients and dissolved gases. And, the blood cells are the red blood cell, white blood cell and the platelets. The red is the blood is red in color because of the red blood cell, and then you have the main function of the blood is to transfer or transport oxygen and carbon dioxide and that mainly happens with the help of hemoglobin which is present in the red blood cells; and it also functions to maintain the acid base balance. Do you know what do you mean by viscosity? Would have heard about it. You know, viscosity is a physics term wherein it determines the thickness of the fluid.

So, the more viscous the fluid is, the resistance is going to be more. That is, more thicker the fluid is, the resistance to flow is going to be more. To compare yourself, you know, example of a water flowing and an oil spilled down on the floor flowing. So, oil is thicker. So, obviously, the flow will be slower because of the increased viscosity.

So, why it is important because more thicker the blood as such the blood is two times thicker than water. Then if it is more thicker because of the increased cellular components, it can compromise blood flow. This is important to know because there are various connotations in the application in exercise training. So, to summarize: the part one of this session we discussed about various components of the cardiovascular system: the function and the chambers and the valves and the blood flow which happens in the heart, the different types of blood vessels and the components of blood and their function. So, if you want to have additional in-depth knowledge about this, you can also refer to these standard textbooks. Thank you.