Sports And Performance Nutrition

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Week-04

Lecture-17: Energy systems and biochemical pathways

Hello everyone. Today we are going to be diving deep into energy systems. If you are wondering how every sport is different and how does the rice, roti, dal and all the vegetables that you eat converts to eventually fuel for exercise. Understanding these energy pathways can be very useful for us to relate it to several sporting activities. So this will involve a bit of biochemistry, different types of sports, different energy substrates and energy systems and how each of this energy system can be a fuel for different type of physical activities. Let us get started.

ATP is the energy currency for every cell. Food fuels exercise and without energy an athlete cannot perform exercise. Going back to the basics of macronutrients, where did we get this energy from? Carbohydrates, fats and proteins. These are nutrients we eat in larger portion and these are also what give us energy for exercise.

Carbohydrates and proteins give us 4 kilocalories per gram and fat gives over double which is 9 kilocalories for every gram. There is some amount of glucose after the food is broken down and all the other excess carbohydrate gets stored in the liver for use in the future. To revisit this concept 80 to 100 grams of glycogen is stored in the liver and that can be used up anywhere between 1 to 1 and a half hours based on the intensity of the activity. Other than the liver glycogen excess carbohydrates are also stored as muscle glycogen. Interestingly liver glycogen can break down to glucose and supply it to the rest of the body for physical activity whereas the glycogen stored in the muscle can support the muscle that is performing the activity.

Also to remind you there is also a large amount of adipose tissue or fat in the body. So triglycerides and fatty acids also become a very important fuel source for endurance exercise and we will learn about it more in the coming minutes. By now you already know the rice, roti, bread, aloo, fruits, milk all of which contain some form of carbohydrate are also energy yielders and convert to glucose. I just talked about how fats can also be the fuel source. In addition there is also a molecule called creatine phosphate in the muscle and that can also be an independent source of energy even when there is no oxygen supply.

The most important thing to note here is that all of these three combined together can be offering energy for exercise. So for a physical activity energy can come from creatine phosphate or glucose or the fatty acids. But do note based on the type of sporting activity there can be one dominance or one predominant source of energy of the others. So the type of physical activity, the intensity, the Vivo2 max or the oxygen supply can determine which of these can be the source of energy of fuel for that particular exercise. This slide captures what I just conveyed to you in the past couple of slides.

The Phosphagen pathway is useful for explosive power or activities that last 10 seconds only. The glucose breakdown which is aerobic glycolysis can last in activities up to a couple of minutes. In physical activities which spans beyond 3 to 5 minutes in addition to burning of glucose for energy when there is adequate oxygen supply, fatty acids are also broken down or oxidized as fuel for energy. So the intensity, duration and the exercise type can be the deciding factor in which of these pathways takes dominance. The ATP-CP or the Phosphagen pathway can give power for high intensity workout.

In adequate supply of oxygen where one can breathe comfortably, glucose is broken down and for longer distance of activity with the supply of oxygen along with glucose even fats are broken down. So what happens when an athlete is running super fast and is gasping for air? In that situation or physical activity glucose or carbohydrates are still used as fuel for that exercise. However it may not be fully broken down and that anaerobic system where there is a dirt or inadequacy of oxygen and this can give you an idea of how a marathon runner can sustain few hours of activity. Let us learn more about what happens in this kind of a sporting event. So from the marathon running video I would like you to relate to what is going on in this energy system of glycolysis.

The runner is working out at a very steady state and carbohydrates are being burnt for energy. It is a low intensity exercise. In endurance events please do note along with carbohydrates even fats contribute to equal amount of energy that is being used and we will learn about that too. So some other examples of this sports will be long distance swimmers, triathletes, cyclists where the exercise lasts for few hours with a VO2 max of about 50 to 60% which is the oxygen uptake. Carbohydrates are being broken down to pyruvate which is an intermediate or a product formed in between and that moves into the mitochondria of the cell or the tricarboxylic acid cycle and eventually in the electron transport chain ATP is used up to release carbon dioxide and water.

So this is the breakup of glycolysis and the tricarboxylic acid cycle. So in low intensity exercise when the oxygen supply is steady aerobic respiration can take place and for those of you who studied some basic science you would have already been taught of how eventually all the food we burn releases carbon dioxide and water. Let us understand what is the difference between aerobic glycolysis and anaerobic glycolysis. When the intensity of the workout increases and the VO2 max can go beyond 80% which means the maximum oxygen uptake is challenged the demand is higher where you are gasping for air and the oxygen supply can fall short. In that scenario when there is less supply of oxygen the glucose does not break down completely and there is a byproduct which is formed and that is called lactic acid.

This energy system comes into play where there are multiple sprint activities which can be typically seen in speed endurance in team sports such as football and hockey, cricket even in racquet sports as badminton, squash and tennis. In these kind of sports even including short distance swimming where there is intense activity which lasts a couple of minutes the anaerobic system comes into play. So in a normal scenario with adequate oxygen where glucose would break down and go into the mitochondria of the cell to convert to ATP in anaerobic system the pyruvate converts to lactic acid buildup. So in my practice I often hear athletes complain of a burning sensation and they could not proceed with the exercise especially in competitions and that is nothing but the buildup of this lactate which can lead to acidosis and can challenge the physical activity. But there is hope that this buildup of lactate is temporary and it just takes a little time for its clearance.

So an athlete who can actually train to build his lactic acid threshold can actually sustain workouts with higher lactic acid. So the body has a fine homeostasis or balance where this lactate molecule is sent back to the liver and reconverted to glucose. This slide here gives a comparison of what I just walked you through the concept of aerobic glycolysis and anaerobic glycolysis. So now you can relate to what is an anaerobic pathway where this batter is running between the wickets to make multiple runs and they may have to do this several times. So this can explain how there is a deficit of oxygen and in team sports where the glycolysis can lead to lactic acid formation.

Here in this video you can see a tennis player and you can see from her physical activity how she has multiple sprint actions and the volley can last up to a few minutes. So racquet sports also is an example where you can correlate to anaerobic glycolysis. Let us move to the next energy system which is the phosphagen or the ATP-CP pathway. Creatine phosphate pathway is independent of oxygen. Creatine phosphate supports high intensity workout.

The highlight energy for just a few seconds of activity and that can be limited to as less as 10 seconds. So this kind of powerful movement is seen where you need huge bursts of energy and that can be examples of sprint activities or even power lifting. The speed and the power needed by this bowler is so intense that you need to conjure up that energy within just a few seconds. In these kind of high intensity activity, creatine phosphate sustains the need for high energy by offering 1 phosphate to make up to the last ATP. So the creatinine stored in the muscle can be very useful for immediate energy.

So to sustain this high demand for energy by re-adding 1 phosphate molecule to adenosine diphosphate, we immediately regenerate adenosine triphosphate or the ATP and that becomes the currency for exercise. In this video you can see the athlete who is strength training. There is a need of high energy for explosive power for strength training and this is where the creatinine phosphate comes into play to give that extra edge. So in strength training and power lifting you can relate how creatinine phosphate pathway can be an energy system. Even in the swimming events which are sprinting activities which can last less than 30 seconds, the first 10 seconds of energy can come from creatinine phosphate pathway.

And of course thereafter after 10 seconds you have anaerobic glycolysis because of the high demand of the workout. I hope these videos help you to put a context to this biochemistry. Givine phosphate pathway also is the primary fuel source for sprint activities be it 100 meters running or athletics or javelin throw. Let us understand what is fat oxidation. I have been talking about the maximal oxygen consumption of vivo2 max and we learnt of how during a high intensity activity or higher vivo2 max only carbohydrates can be the source of exercise energy.

So the contrast of that is the beta oxidation of fatty acids where at a lower intensity fatty acids can be the fuel for exercise. Fats can be burnt only with a steady supply of oxygen and hence any physical activity that is at a lower rate can support this. Please do note that the conversion of fat to fuel is a very slow process and thus can offer energy at a slower rate. Fat oxidation can be seen alongside glycolysis which is breakdown of carbohydrates in endurance events which last longer duration as I already gave some examples which are marathon running, triathlon, cycling. This is the biochemistry pathway where you can see the fatty acids are being broken down through beta oxidation and the byproducts are pushed into the tricarboxylic acid cycle for providing energy or ATP.

From long distance cycling to any exercise that goes beyond 3 to 5 minutes uses fats as fuel. As shared from the video in endurance events there is also the type of muscle Fiber which plays an important role in determining which type of macronutrient we use as energy substrate. Typically in endurance activities we have the slow twitch muscle Fibers and they can use up more fats for oxidation. So the slow twitch muscle fibres are slow to fatigue and thus can support longer exercise duration. So to summarize all physical activity is always a combination of different energy systems.

However based on the intensity and the duration of exercise carbohydrate becomes fuel for high intensity workout which last shorter duration. Creatin phosphate pathway supports high intensity exercise which last about 10 seconds only and this is independent of oxygen availability. Along with the creatin phosphate pathway for high intensity or sprint activities anaerobic glycolysis can support this type of exercise when there is a higher demand for oxygen and deficit of oxygen supply. Fats and carbohydrates become the source of energy for low intensity longer duration of physical activity when there is a steady supply of oxygen. I hope with the examples of these sporting events you could relate to the concepts of the complex biochemistry and the energy pathways.

Thank you for listening.