Introduction to Exercise Physiology & Sports Performance

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Lecture – 32

Hydration and Fluid Balance (Part -2)

Welcome back to this NPTEL course on introduction to exercise physiology and sports performance and to this module on hydration and fluid balance.

I am Dr. Chandrasekara Guru. I was discussing about various aspects of water balance in the previous part. So, in this particular module, we are intended to learn on water function and balance, dehydration and its role in performance and this we have covered in the part 1.

In this part, we will be addressing about the electrolyte regulation, how to calculate sweat loss and sweat rate, and certain concepts of sports drink and the recommendation there on.

So, let us revise what we saw in the previous part of this module. So, we learnt that various functions of water, the balance that is maintained during rest, as well as when the body temperature increases during exercise or when the external body temperature changes. What is the effect with respect to exercise on water balance? What are the various effects of dehydration on performance and various dehydration grades? We have also seen various indices that one can use to assess dehydration status, how a body responds to dehydration by means of stimulation of thirst, and how this particular reflex is sluggish, and how can we externally replenish the fluid by means of following certain recommended methods. We also discussed on various practical recommendations in terms of manipulating the gastric emptying, and then thereby you can increase the availability of water in the plasma at the right time during the event as well as after the event.

So, to proceed further with respect to the electrolyte, the electrolytes determine the concentration of the fluid in the body components, referred as the plasma osmolarity. So, the plasma osmolarity is determined by the electrolytes in the body components, and the extracellular fluid is at equilibrium to the intracellular fluid. And it is maintained because there is easy transfer of water between these two compartments of the body. The normal osmolarity of plasma is 280 to 295 milli osmoles per kg of water, because water is the major denominator in the maintenance of plasma osmolarity. So, the main electrolyte in the intracellular fluid is potassium, the main electrolytes of the extracellular fluid is sodium and chloride. So, in fact 90% of the plasma osmolarity is maintained by the sodium and chloride, which composes of about 275 of the total normal osmolarity of plasma. So, that brings to the fact that sodium determines the plasma volume. And along with sodium you find the chloride moving, so it is predominantly the sodium which determines the plasma osmolarity. And which organ regulates this, it is the kidney. Kidney regulates the electrolyte balance by controlling the transfer between sodium and chloride.

So, what is the balance? At rest we find the equilibrium is there between intake and output. The daily input is contributed mainly in terms of metabolism, the fluid you drink and the food you take. Here an important aspect is that the fluid intake is regulated by thirst mechanism and the

food intake is regulated by the hunger mechanism. The daily output is in terms of sweat, so you lose some amount of electrolytes through sweat, faeces as well as through urine. So, in case of exercise there is increase in the fluid loss and this increase in water loss also, there is also increase in the electrolyte loss. So, this loss of electrolyte and water from the body causes an imbalance.

So, in case of exercise what about the electrolyte loss? So, we saw that there is definite increase in the water output by means of skin and increasing in the ventilation. So, you have increased the sweat as well as through the ventilation and some amount through the urine. So, let us focus on the electrolyte loss. When we see the electrolyte loss it happens through mainly two mechanisms, one is the urine and the other one is the sweat. So, urine becomes the major contributor for electrolyte loss during rest. So, when you are not doing any activity majority of the electrolyte is lost through urine and kidney controls that. Whereas when you do exercise we have seen that there is massive increase in the sweat loss. So, when the sweat rate increases you lose lot of water in addition to that you also lose some amount of electrolyte.

So, let us see how the kidneys regulate the electrolyte balance. So, there is fluid loss, when there is fluid loss you have two things that is happening, that is change in the plasma volume and change in the plasma concentration. So, now let us focus on change in the plasma volume, how it kind of regulates the electrolyte balance. So, because of the change in the plasma volume it stimulates volume receptors in the kidney. So, as soon as these receptors are stimulated it further activates two different mechanisms. One is by neural mechanism through the sympathetic nervous system and the other one is by the stimulation of the hormones. So, by stimulating the renal sympathetic system it results in kind of decreasing the glomerular filtrate. What is glomerular filtrate? So, the functional unit of the kidney is called as the nephron. So, the nephron has the initial head part where you have the glomerulus part where the intertwining of various blood vessels happen and the filtration of the excretory or the waste products happens at this level. So, majority of the fluid or the solutes are moved in through this glomerulus and it finally forms the filtrate. So, the stimulation of the sympathetic nervous system it reduces this filtrate per se in an attempt to save the losing of electrolyte. Second thing which happens is and this per se will reduce the sodium loss. The second thing which happens is the increase in the absorption. So, normally when this filtrate is kind of secreted from the glomerulus it goes through another part of the nephron called as the tubules. So, there are different parts of the tubules and as the fluid passes through this tubule all the necessary electrolytes which are not considered waste products are reabsorbed by the body. So that it can be reused. It is kind of a mechanism by which you reabsorb the necessary products which are secreted by the in the glomerulus. So, as the glomerulus filtrate passes through the tubules they are reabsorbed. So, because of the increase in the sympathetic drive there is also increase in the reabsorption of the sodium. So, this again will prevent sodium loss in the urine. The third thing which happens is the sympathetic system per se also stimulates the release of renin in the kidney. So, as and when the kind of hormonal system is triggered, hormonal system results in kind of release of atrial natriuretic peptide. So, the atrial natriuretic peptide which is released in the body is reduced with the decrease in the plasma volume. So, as this is reduced this also kind of decreases the sodium loss. You remember the renin is released because of sympathetic system. In addition it is also kind of stimulated through the hormonal mechanism called as the renin angiotensin aldosterone axis. So, because of which there is increase in the concentration of the hormone called aldosterone. This aldosterone is also responsible to increase the sodium

reabsorption by the kidney. So, that further decreases the sodium loss. So, this is the broad mechanism by which the kidney tries to save the sodium which is being lost in the urine. What happens when the change in the plasma concentration happens? The change in the plasma concentration causes stimulation of the osmotic receptors. This change in the osmolality. So, the osmotic receptors are triggered in the hypothalamus. So, that causes lot of stimulation of an or release of an hormone called as antidiuretic hormone. The name signifies antidiuresis. Diuresis means secreting, increasing the urine. So, antidiuretic means it will reduce the urine output. So, by which it tries to conserve the water that is secreted from the glomerulus. So, water is reabsorbed in the kidney. So, thereby this causes decrease in the water loss. The other mechanism is stimulation of the thirst center. So, because of the stimulation of this thirst center, you tend to drink fluid from outside. So, intake of fluid also causes kind of counters the water loss that is there. So, because of these two aspects, you will have the conservation of the electrolyte and water which is being lost by the kidney through this route.

Whereas in case of the other aspect of electrolyte loss is through your sweat. So, let us see how sweating is kind of attributing to this electrolyte balance during the exercise. Like human sweat, it is nothing but filtrate of the plasma. Similar to urine, the sweat is also is a filtrate of the plasma. So, this is happening at the level of specialized eccrine glands called as sweat glands which are located along the skin of the body. So, they are mostly concentrated on the foreskin and on the palms. It is secreted by the eccrine sweat glands which is present in the skin. Though the sweat is salty, it is seen that it has 99% of water. So, the taste is because of only the one third concentration of sodium chloride as compared to the plasma. So, not again much of electrolyte is lost in the form of sweat. The sweat generally contains sodium, chloride, potassium, magnesium also as well as calcium. But then it is in a very meagre quantity as compared to the plasma. During endurance events when we discuss that the sweat rate may increase up to 1 liter per hour. Even in such cases also, the body tries to conserve the loss of electrolyte and the loss is really minimized. They say that it doesn't exceed more than 5 to 7% of the sodium chloride concentration in the sweat as compared to the plasma. So, hence, it does not have any kind of measurable electrolyte loss in this sweat. So, it generally doesn't contribute to decrease in the performance during exercise.

So, how this sweating mechanism is regulated? Whenever there is an increase in body temperature, sweating basically as we discussed is to dissipate the heat by the process of evaporation. So, when the body temperature increases, there is stimulation of the anterior hypothalamus to kind of via the sympathetic nervous system to the sweat glands. So, the sweat glands causes increased secretion of the sweat based on the blood flow which is available at the skin. So, we also discussed during the cardiovascular system and exercise module, there is a redistribution of the blood that happens during exercise. So, the blood which is normally spent more about 50-55% blood that is distributed to the splanchnic circulation is redirected to two important organs. One is the exercising muscle where there is actual demand and second is the skin. So, the skin receives more blood supply during exercise. It is basically to prevent the rise in the body temperature by the action of sweat glands. So, this particular increase in the sympathetic nervous system derived to the sweat glands causes increased secretion of the sweat. Once it is secreted, it passes through the duct. Before through the pore, it comes out the skin as sweat. So, in this transit process, as the sweat filtrate passes through the duct, the body tries to conserve whatever the sodium that has been secreted into the sweat filtrate. So, the sodium is again reabsorbed in this duct as the sweat passes to the top of the pore from where it

gets released out as sweat. So, the secretion per se is rich in about 95% or 99% of water and less amount of solute which is present there. So, that is why at the final stage when the sweat passes out of the skin, it is predominantly water and less of the salt. That is the electrolyte is reabsorbed. So, there are various factors which can affect this particular reabsorption process. So, one needs to understand this process so that we can avoid electrolyte loss. So, one is exercise intensity. So, when the exercise intensity increases, obviously the sweat rate will increase. So, when the sweat rate increases, there is more sweat which is being secreted out of the skin. So, the time available for the sweat to pass through the duct is less. So, the speed of the flow aspect is increased to control the increasing body temperature. So, there is not adequate time for the body to reabsorb the sodium. So, because of this the sodium is lost. So, in prolonged ultramarathon and long duration endurance events, there may be associated sodium loss also. So, that is the reason we earlier discussed that until duration lasting one hour, generally it is only the water loss that is there and less of the electrolyte loss. So, it is enough that you replenish with water alone. This is for this reason. The other aspect actually stimulates more sodium reabsorption. That's why I have shown this in green. So, here acclimation. Acclimation is a temporary process by which your body adapts to the outside ambient environment. So, we said that one because of the exercise your body temperature increases and the other one because of the hot weather outside. So, ambient temperature also makes your body to react and increase in the body temperature because of passive increase in the heat outside. So, in such climate if there is an exercise event, what generally athletes do is they go to the event at least a week or 10 days and then they get used to the climate. And that process of using, you know, getting used to the climate by the human organ system is the acclimation. It's a temporary mechanism by which you adapt to the external rising body temperature. So, that kind of promotes more reabsorption of sodium. So, in these individuals who have got acclimated to the hot weather will lose more of water rather than electrolyte along with that. Also repeated training. So, when you get trained more and more, so you get used to the exercising temperature, body temperature, rising their body temperature because of the exercise. And then accordingly your body gets used to it. And then even though there is an increase in the transit time, the sodium absorption is made. And the other aspect is whenever there is an increase in the release of aldosterone, which we seen earlier, aldosterone tries to kind of reabsorb sodium from the kidney in the tubule. Similarly, it also tries to reabsorb sodium at the sweat gland level as well. So, these are the factors which will affect the reabsorption of sodium in this process. However, the sweat glands per se are dependent or very individualistic. You cannot have a general, generic sweat rate or sweat loss for every individual. There are a lot of factors which determines the sweat rate and the sweat loss. So, these factors are also important for us to know so that accordingly we can understand the body of that athlete and then accordingly we can replenish. So, it varies with age, gender, the genetic potential of the individual per se. So, it also depends on the fitness level and the training status. So, that again kind of have an influence on the sweat rate and the sweat loss. Also, the clothing that you wear. If you wear more of a thick clothing, it cannot easily evaporate. So, obviously that has a major impact on the sweat rate and sweat loss as well. As well as the humidity. So, we discussed earlier that increase in the humidity outside also reduces the evaporation of the sweat. So, that again influences the sweat rate. So, knowing these factors is very important. So, with maximal sweat rate can go up to 30 ml per minute. And during marathon events there is a massive increase in the sweat rate at the rate of 1 liter per hour. So, for an event of a full marathon there may be a loss of about 2 to 3 liters of fluid loss as sweat. And this may even constitute about 6 to 8% of body weight. So, we saw

earlier that reduction in the body weight of loss of fluid loss, loss of fluid in terms of more than 2% itself can lead into heat illnesses in the exercising athlete. So, this is a gross reduction in the performance as well as increase in the chances of heat illness. So, it is always important to understand what is the sweat rate and the sweat loss of that particular individual during that particular event, during the training period itself. So, that when training you know what is the sweat rate, what is the sweat loss and accordingly you can plan the fluid replenishment for that particular individual and specific to that particular sports.

So, it is important to know how do you calculate sweat loss and sweat rate. It is very simple. So, sweat loss during exercise can be calculated by just measuring the body weight and whatever fluid you take, whatever fluid you lose out. It is just simple mathematics. So, wherein you will have to just weigh the individual before the event and after the event. And just record the fluid that the individual drinks during the event and in case the individual passes urine that needs to be subtracted from the total fluid intake. So, that gives the net fluid that has been taken by the individual. This has to be subtracted from the difference in the body weight. So, that will give you the sweat loss. So, what is sweat rate? Sweat rate is nothing but with respect to the time. So, whatever the sweat loss that you calculate divided by the duration of the exercise. And if you want it in hour then you multiply it by 60. So, that gives you the sweat rate calculation for that particular individual for that particular activity. So, it can be expressed as ml per hour or ml per minute if you do not multiply by 60.

Sweat Loss during exercise= (Pre-exercise body weight- Post-exercise body weight) – (Fluid consumed during exercise – Urine passed during exercise)

Sweat Rate = Sweat Rate during exercise ÷ Duration of exercise performed (min)/60

So, let us see an exercise. So, here we have Ms. Malini, you are training her. She is an amateur runner. And you find out that her body weight is 55 kg. And you plan a slow long distance training for a 25 km during a pleasant early hours of the morning. So, there is not much of external rise in temperature. And this is her first long run. So, you also wanted to take this opportunity to kind of calculate how much she is losing by means of sweat. So, you wanted to calculate the sweat rate as well. So, you advise her, since she is a fresher, you advise her to drink 100 ml every 15 minutes as she is doing the practice. So, you are accompanying her along with her in a cycle and you are giving the fluid as well to her every 15 ml. She completes her training over 2 hours. So, she ran 25 km, she completes it over 2 hours period. Her post run weight also was checked. So, you checked it was 53 kgs. And in between she did not break off to, you know, for nature call or passing urine. So, she was comfortable. So, now how do you calculate the sweat loss and sweat rate? So, we know that weight was 55 kg before the event. After the training it came down to 53 kg. And the duration is 2 hours, so 120 minutes. What about the fluid consumed? So, you are given 100 ml every 15 minutes over 2 hours. So, that becomes 800 ml. She did not pass any urine. So, the urine output is 0 during this particular period. How do you calculate the sweat loss? Sweat loss is difference in the weight, that is about 2 kgs. Then you also have to calculate the net fluid that is being consumed. So, fluid consumed is 800 ml and she did not pass urine, so 0. So, it is about total net fluid consumed is 800 ml. So, 2 kg weight loss, for the ease of calculation, we consider each kg leads to 1 liter

of, 1 kg is equal to 1 liter of weight loss. 1 kg of weight loss is equal to 1 liter of water loss. So, 2 kg, let us assume 2000 ml of water has been lost by means of body weight. So, 2000 minus 800 gives you 1.2 liters. So, 1.2 liters is the sweat loss of this particular individual.

Sweat Loss= (Pre-exercise body weight – Post-exercise body weight) – (Fluid consumed - Urine Loss)

= (55-53) – (800 ml – 0)

= 2 kg – 800 ml

= 2000 – 800

= 1200 ml

How do you calculate the sweat rate? So, divide this by the total duration. So, 120 minutes, that will give you, that is equal to 600 ml per hour. So, the individual has lost 600 ml per hour and that is the sweat rate. So, over 2 hours she has lost 600 ml and good that you have also replenished some amount of fluid. So, now based on this you can also now plan her in the next event wherein she can increase the intake. So, the loss will be further reduced. So, 600 ml corresponds to about say roughly 0.5 kg of weight loss. So, that is okay. And so, for a 50 kg individual, 2% comes to 1 kg of body weight. That is about 2% dehydration that may impair the performance. In this case, it comes to about 1%. But still the endeavor needs to be to prevent even that situation. So, you can even increase the fluid intake during the event or she can start the event in a hyper-hydrated state per se.

So, with respect to fluid replacement, we have seen this earlier as well. So, before event our endeavor is to maintain at least euhydration or if not you can also increase to hyper-hydration. And the hydration should be maintained by taking at least 5 to 7 ml of fluid per kg body weight 4 hours before. So, that by the time you start you have emptied your bladder and you are ready for the race. And if you have less time then at least 2 hours before you have to take 3 to 5 ml per kg of body weight of water. Then during the event based on the duration and the intensity you can replenish the water basically to prevent dehydration. So, based this is preferably replenished based on the sweat rate and the sweat loss for that particular individual, also based on the duration and intensity of the exercise. So, this needs to be calculated during the practice session itself. So, during the event, you already know how your body is going to respond and how much amount of fluid is required for you. So, this answers the question that we have raised initially that was raised by Ms. Vanishri. So, as a general guideline, it is 150 to 200 ml every 15 to 20 minutes. Why 15 to 20 minutes? We discussed gastric emptying time. It has something to do with increasing the gastric emptying so that it is immediately available to the plasma. And after the event, once the event is over, so we need to rehydrate the loss. So, the rehyderation can be done in a gradual way but then the amount should be 150% of whatever the fluid that has been lost. Why? Because adequate fluid is required. Most of the protein repair and the connective tissue repair happens during this period. And this is the time when you have to have adequate fluid volume for the transport of the waste products away from the exercise muscle also to supply the fresh blood to the muscle. So, you need to maintain the cardiac volume. For that, you need to replace at least 150% of the fluid balance. And it is important to include electrolyte in this stage so that the thirst response is also increased. And over the post-exercise

phase for 24 to 48 hours, the individual can slowly replenish the fluid with the thirst response as well.

So, the practical recommendations here we discussed it previously also. I will again cover it depends on the gastric emptying time. So, various factors are there which determines the gastric emptying and so that it is available at the intestine for immediate absorption. So, that can be, these factors are the temperature, the fluid volume, that's why you replenish every 15 to 20 minutes. Caloric content, if they have some macronutrients providing energy then the gastric emptying is kind of decreased. Fluid osmolarity when the concentration is too high then again it is decreased. So, exercise intensity is too high again it is decreased. pH beyond the normal range it affects gastric emptying, hydration. And if it is very too low then the gastric emptying is decreased. So, it is important to add some amount of glucose also to the solution. So, that glucose by kind of maintaining that optimum concentration between 6 to 8 can help in absorption of water as well as the electrolyte. So, now to the solution you need to also replenish the electrolyte. So, you need to add some sodium as well. Sodium it is not only going to replenish the electrolyte but also it stimulates the thirst. So, that subsequent during the slow recovery phase also the athlete can have the sensation and kind of replenish the lost fluid. And we have discussed this earlier when the duration is less than 1 hour then water replenishment is not required that you should replenish the electrolyte because the electrolyte loss is not that much.

So, you also need to know about sports drinks. So, sports drinks are generally designed to suit the energy and fluid needs of the athlete as per the event. So, the salient features when you say sports drinks, the salient features are it should be palatable, taste-wise it should be pleasing for the athlete to consume. It should be isotonic. Isotonic would mean it should be the same as per the plasma concentration if you see. It should be the same as per the plasma. So, isotonic is the word that we use for the same kind of tonicity or the tone of the drink, and the plasma should be the same. There should not be any discomfort after having this particular drink because you are going to consume it during the event as well. So, it should not interrupt in terms of your performance. An important aspect that one needs to consider is the effect that it has on the gastric emptying. So, it should be such a fluid which can empty immediately from the stomach so that it is available for absorption. So, with this kind of preload, sports drinks are ready-made drinks which can be made from naturally available resources or they are also available commercially in a pre-made form. So, they can be consumed before the event, during the event as well as after the event. The commonly available drinks that you can prepare from your own resources which are naturally available are coconut water, lemon water with salt and sugar, chocolate milk in the recommended calculation of the sugar content. So, these all can form good kind of sports drinks, naturally available sports drinks.

The key points that one needs to consider are, as a sports drink you are looking at two different aspects. One aspect is energy. So, it should be a drink which is able to replenish the energy as well during the event and also post-event during the recovery phase. And the second aspect is the sodium replenishment as well as the water replenishment. So, you are looking at the energy delivery as well as the sodium and the water delivery. So, with respect to energy delivery, if you see there are two aspects to it. One is the concentration. We have seen time and again we have repeated that carbohydrate concentration affects the gastric amine time. So accordingly, then the constituent also should be. The concentration should be anywhere between 6 to 8% of the solution. 6 to 8% would be in 1 liter of water if you take, if you had 6 grams then it becomes

6% of that particular glucose. So, you take 1 liter of water, add 6 grams of glucose to it, that becomes a 6% solution. So, such a solution should be ideal for immediate absorption and increasing the gastric time. The other aspect is the content. What is the carbohydrate that you are using? So commonly used content is glucose. You can also have a mix of two different carbohydrates. It can be glucose with another carbohydrate maybe in the form of sucrose or fructose. Why? Because glucose has its own transporters that transport it from the intestine to the plasma. And you also have sucrose and fructose which also get transported to different types of transporters. So, you are trying to kind of leverage the different type of transporters available. So, two different combinations of carbohydrate also works well. And you also have sometimes polymers, glucose polymers like maltodextrin also used in combination with glucose as carbohydrate content. So, all in all, whatever be the content of the carbohydrate, the concentration if maintained to 6-8%, it is seen that it increases the performance.

This is about the energy delivery. Let's see about the points with respect to the fluid and electrolyte rebalance. So, rehydration requires not only water, it also needs sodium. Why? Sodium and the inclusion of carbohydrate to the solution will improve not only the rehydration aspect, also it supplies energy which is required, and it also helps in further reabsorption of water and sodium. And also, it increases the thirst, so you tend to increase the fluid intake. Further, sodium addition to all of you would have tried adding some amount of salt to the lemon water increases the taste as well. So, you tend to drink also more. So, you rehydrate well. And with respect to the concentration during and post-exercise, the sodium concentration should be maintained to 20 to 60 millimoles per liter in the rehydration fluid. So, how do it transfers practically? So, one teaspoon of common salt that we take in cooking, take one teaspoon of common salt and that contains about 2300 milligrams of sodium. And it corresponds to about 100 millimoles per liter of sodium level. So, if you want to make an ideal sports drink for your athlete, you need to add half teaspoon of common salt to one liter of water. And you can also add 6 grams of glucose as I said previously, so that becomes a good ideal sports drink for rehydration purpose as well as for energy delivery.

So, it appears that everything is very well defined, everything is recommended, so it's been taken care of. But then it again depends on the need of the athlete. So, you need to evaluate the sport, you need to evaluate the duration and intensity and the timing with respect to the intake. You need to know exactly what is the sweat rate and sweat loss by the athlete so that accordingly you can view. The experiment should with respect to the content and the concentration should be done during the training phase. So that during the event you are able to give the right composition and the concentration of the fluid for rehydration and energy delivery. Also, it is seen that if you start the event in a hyperhydration state, the performance level increases and it prevents the chance of heat illness as well as the dehydration state. Sometimes overzealous water intake not high in electrolyte, only water intake can result in dilutional hyponatremia and that can cause confusion, disorientation and can even lead to coma and in case of some death. So, a typical sports drink is to need to replace water, electrolyte as well as deliver some amount of energy during the event as well as after the event. So, this needs to be again chosen as per the individual's palatability of that particular fluid.

So, to summarize hydration and fluid balance, we went through various ways by which the electrolyte is distributed in the body in terms of extracellular fluid because of the sodium in the intracellular fluid, the calcium, sorry in the intracellular ecause of the potassium and the equilibrium is maintained between the ECF and the ICF. The balance that happens during rest

as well as during exercise, the role of kidneys and sweat in regulation of the electrolyte balance, how do you calculate the sweat loss as well as the sweat rate for that particular event. And what are the various recommended methods and quantity by which the fluid replacement should be undertaken. And we also discussed in brief about the aspects of sports drinks, what is the major aspects that needs to be considered in choosing a sports drink, the features, the requirement or the principle behind the choosing of the right sports drink for your athlete.

So, the takeaway points from this particular module is that water and electrolyte regulation is interrelated. And the regulation of fluid during exercise, it depends on the hot weather, the intensity and the duration of the exercise. Sweat rate is individualized, it depends on multiple factors that I had brought out. So, all these factors have to be considered. Acclimation obviously will help in better conservation of electrolyte. And a typical sports drink will contain water, glucose, salt in appropriate concentration so that the absorption is optimum. And a typical sports drink can be prepared easily at home by just adding 6 grams of glucose and half teaspoon full of common salt to 1 liter of water. That becomes your ideal sports drink.

Thank you for being here with me. And those of you who are interested in learning more about this particular module, you are directed to the standard textbooks on exercise physiology and sports performance.

Thank you.