Exercise Physiology- Part 1

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OK, my name is Dr Andy Klein and we're going to be going over exercise physiology principles this weekend. How many of you remember the Krebs cycle? How many of you want to remember the Krebs cycle? You know, in general, you don't. But I think what you'll find is if you have a good basis of exercise physiology, it will help you.

You're probably getting questions from your patients that involve exercise physiology that you're not even aware of, OK? Now yes, if you go out on-- let's say you're a team doctor and you go out on the field to take care of a kid's ankle injury, I've never known anyone to ask, well, what should max V02 before you start taking care of them. So in that sense, you don't necessarily need it right off for the immediate care, but it really does come in handy.

Now, some of the questions you'll get sometimes from the patient, you going to ask them to exercise. That's the big thing these days. When we talk about active care of the patient, it's get the patient to exercise. But what the patient wants to know is, well, can I get hurt from exercise? These are the type of questions.

Can exercise kill me? We always read in the papers every once in a while, someone goes out for a run and it does kill them. All right? So we would like to prevent that. That's really not good for the patient.

But if we just take a basic thing, and this is how we can explain it because exercise is not good for everyone. There are cases where they shouldn't be exercising. There are also cases where it's a risk. So let's just look at this for a second.

I want to look at two people. One is a sedentary person and one is an active person. OK? And we'll say they're 40 years old. So what we're looking at is a sedentary person. What would be a normal resting heart rate for them? Let's put 80, all right? It might be a little bit lower but we're somewhere in that 70 to 80.

Versus the person who's active, who might only be at about 60. Now, if we multiply that by 24 hours, what we can see is during the day, look at the difference in heartbeat. About 500 heartbeats a day you're saving the heart as a muscle.

Some physiologists believe we're actually obsolete after a certain amount of beats. We have a certain amount of beats in our life. Some people say, well, I don't want to use them running. But in fact, you'd end up using less, OK?

This is the old Bill Russell story. Bill Russell, who played for the Boston Celtics, did not like to practice hard. He felt that he had 10,000 rebounds in his body and he wasn't going to waste any in practice. He was only going to use them in games. But we can see that, in fact, you would be saving heartbeats.

Now, let's look at this. What happens during that hour, though, that you do exercise? What would be a normal heart rate that you might go up to? 160? OK, so 160 beats per minute times 60. You're actually adding 960 beats an hour. But you're only exercising for and hour, so even taking that into account, you're still doing less beats per day.

Over a 10 year period, we worked this out once, over a 10 year period, it can come out to like a billion beats, which is a lot. All right? So we can see that your heart rate can go up to 160.

Now, this is why you need to understand some of the basics of exercise physiology. If someone is sitting in your office now, they're breathing hard, they're sweating profusely, they're feeling some chest-ness around. And they have a heart rate of about 170. What would you do?

Would 9-1-1 be a reasonable response? However, I've just described someone who just went out for a run, OK? So what we see is exercise actually creates the parameters which we consider disease parameters. And that's what it is. It is a risk when you exercise, but what it is is a controlled risk.

When we exercise, what we're saying is we're going to control our risk, we're going to supervise our risk for one hour a day so that when we go out at night to shovel snow, we're not going to have a heart attack. And that is the purpose of exercise. Every exercise has a disadvantage.

There's a risk to every exercise, but there's also a benefit to every exercise. If you can match up the benefits and limit the risks, you're doing a great job. Now, if we talk about shoveling snow, I just wanted to ask you, I was thinking about this other day because I have such bad knees, all right?

I'm going to first start about introduction to energy transfer and we will try and attack this also from a clinical standpoint. And when we look at the introduction to energy transfer, what we're talking about is a continuous chemical energy. That's what's going on. Right now, you're using energy. Maybe not much, but you have to use energy.

We can not use heat energy. We don't just, you know, start a fire in our bodies and burn kindling. We would spontaneously combust, we would actually burn up. Our blood would boil, we can't handle that kind of energy. So we have to use a continuous chemical energy. And that's what we do with the phosphate bond energies.

Now, the main one that you'll see is ATP. Adenosine triphosphate is the major energy source. The reason why we're going to learn this is now we can figure out whether the supplements they're selling us will actually work. How good are these supplements? Creatine phosphate, creatinine monohydrate, we've got to discuss this since it is relatively common.

So since ATP is our primary energy source, how much do you think we have in the body? We have a total of about 10 ounces. Total. Not even, actually. It's more like two and 1/2 to three. So we have only about two and 1/2 to three and 1/2 ounces of ATP in our body. That's it.

What we do is we absolutely just keep recycling this ATP. 75% of the time, we're recycling ATP. Now, this comes in handy. It seems the reason why we have such a small amount of ATP is because every time we use it, it changes the balance so much, it's a quicker way to initiate all the metabolic reactions.

If we had a lot of ATP, let's say we had three pounds of ATP in our body. We had a little fanny pack and we were carrying it around with us, and you used a couple ounces, relatively speaking, that's not going to make much of a dent and your body won't initiate anything. But by keeping it to small amounts, then every time we use it, we're getting a quick change and that's what's going to trigger a lot of our metabolic responses.

If you sit and then you get up, you increase your energy production about four times. If you take that walk, a slow walk into a run, you're now going about 120 times in terms of energy production. So we have our ATP.

A marathoner who is about 80 kilograms, I think he goes up about 150%. He will double. 80 kilograms is large for the marathoner, OK? But he will almost double in body weight. That's how much ATP he will synthesize in a race, OK?

So we have our ATP. Now, we have a reservoir, creatine phosphate, OK? Now, creatine phosphate isn't used as much anymore, I changed it in the notes. You can see it's now called phosphocreatine. I have no idea why the change, all right? That's just a function of the times.

When I did my master's in exercise physiology, we called it creatine phosphate. Now it is phosphocreatine. So if we look, that is the energy reservoir. So we're going to look at some of these equations in here so you can see what's going on.

Now, what we do is ATP plus water. You can see that reaction there, ATP plus water. And this will be catalyzed by the enzyme ATPase. Will give you ADP plus phosphate. And it's the breaking of this phosphate bond where the energy comes from. These are high energy phosphate bonds plus energy.

That is the basic equation that we're looking to do. Break off that bond. Now, we do have a reservoir and the reservoir is the phosphocreatine What the phosphocreatine does is, it will now add to the ADP. So this ADP now can be used. Phosphocreatine. And that'll create another one.

And now you get another ATP. And you will have creatinine as a waste product. So creatinine and creatine kinase, they are sometimes uses markers to get an idea of how much muscle you're using or how active you've been. Now we'll bring it down to the next equation, the adenylate kinase. Adenylate kinase, which used to be the myokinase reaction. Now it's adenylate kinase reaction.

And in that case, you're taking two ADP and it gives you one ATP and one AMP. AMP, adenosine monophosphate. The key to that is, when you start going into these energy reservoirs, you start creating the AMP. The amp is a messenger. This will start triggering the breakdown of glucose and glycogen.

So if you just did something real quick, you can use ATP, no big deal. But now you're going a little bit further, a little bit more intense. So now you break into the energy reservoir. And if you break into the energy reservoir, that is the key to start producing, getting glucose, the whole glycolysis cycle going.

As you sit here right now, you produce ATP. It takes energy to sit here, OK? Not a whole lot, but it does take a certain amount of energy, all right? Right now, you're producing lactate. Did you know you're producing lactic acid right now? It's a byproduct of energy production.

You're producing it at such a small rate and you have plenty of oxygen to accept the hydrogens, that there is no buildup. So for most of you at resting levels, it's about two millimoles per kilogram. And it's not a big deal. And we'll talk about lactate threshold later and onset of blood lactate. So you can see you have the adenylate kinase reaction. So now that we have just the basic of where we're getting our energy from, now let's talk about supplements.

Creatine monohydrate is the big one I want to talk about because that's what it's designed to do. If you look at creatine monohydrate, and I've given you that, quote, it enhances anaerobic power, it enhances strength. It speeds recovery from interval work. And it does seem to work.

This first came on the scene, you know, whenever you talk about supplements, usually there's some point where they start coming on the scene that someone used it who maybe had been using it and they were very successful. So the creatinine monohydrate really came on the scene in '92. British sprinters and herders were using it.

And they had some very good success and then it started coming out. Unfortunately, a lot of these supplements actually get their beginnings in agriculture. A lot of the athletes are taking supplements that were originally designed to make cattle bigger, which should tell us that it may not be a good idea for humans then. Unless we feel like going to the slaughterhouse also.

So if we look at creatine monohydrate, the question is, are these true? And the answer is yes. It does seem to help. But there are some things we should know about.

First of all, who will it help? It will not help endurance athletes. Creatine phosphate, creatine monohydrate, the supplement, are going to help athletes who are working at intense levels. Resistance, interval work, sprint type work. And they have to be working hard.

Recreational athletes are probably not going to benefit much from taking creatine monohydrate. If they are going to take it, how much should they take? That would be the next question. Now, the original work by Hultman was not in, OK, just take this amount. Because really, when you think about supplements, supplements really should be per body weight, not just a flat out.

Should someone who weighs 120 pounds take the same amount as someone who weighs 240 pounds, you wouldn't think so, OK? And in fact, the original work that Hultman spoke about, that if you're in the loading stage for creatine monohydrate, it would be 0.3 grams per kilogram of body weight. That would be a typical loading. And then once you had loaded the body, then it would become more of just keeping a certain level, kind of a maintenance level.

And for that, it was 0.03 grams per kilogram of body. Now, if we take an athlete who might be 150 pounds, which is about 70 kilograms, you can see that their initial loading would be about 27 grams per day, and their maintenance would be about three grams per day, which in fact, is kind of the general outline given to a lot of athletes, that they should load with anywhere from 20 to 30 grams per day and keep a maintenance level at about 0 to five grams per day. So you can see where these levels come from.

Can you get this from food? The foods that are highest in creatine as a substance would be meat, fish, poultry. And you're going to get about four to five grams of creatine per kilogram of food. So if you wanted a daily dose, just a maintenance dose of five grams, you'd probably have to eat about two to two and 1/2 pounds of steak.

Now, I've heard some of the football players who do eat this kind of amount of food, but they would even need more because their body weight is larger. So the chances are, you're really not going to get it just from your diet. That if you want to supplement, you're going to have to supplement with the creatine monohydrate, OK? So those are the numbers.

Have they gotten good results? Yes, they have gotten good results. But what about side effects? That's the next thing. Now, keep in mind, creatine monohydrate is not a banned substance by anyone. No one bans it. OK?

We're not sure what the side effects are. The longest study I saw that followed it long term was for years and there didn't seem to be any effects. Possible effects, though, are on the kidney. Of course, the kidney is where it's going to be metabolized.

And the other one that they suspect is cramping. Because with the creatine, you get water retention, which decreases the level of electrolytes in the muscle. So it seems to be there's an imbalance due to the osmosis with the water. So cramping, they think, is one of the side effects.

Sometimes they see athletes cramping a little bit more and they suspect it might be creatine monohydrate. That's assuming that they can even get it into their system because some athletes, they'll just get GI distress and can't even successfully take it. There are those cases also.

So you definitely want make sure you hydrate also. And you might want to make sure that you hydrate with some sort of electrolyte solution. Can't really just be water alone, OK? You know, when we look at supplementation, people look at all these different cycles and they try and plug anything they can.

They say, OK, maybe there's a shortage here, maybe there's a shortage there. They tried ATP molecules. Someone once was marketing ATP supplements. You know how big an ATP molecule is? You can't stuff-- no, you could. But I mean, it's not really bio available, it's too large to get through the mucosa.

But people were selling it. How long were they selling it for? As long as people would keep buying it, OK? So that's this other one. So when you talk about creatine monohydrate, it is a supplement that seems to work. And when we're done with this section, we talk about supplements, we'll have to talk about the athletes and the psychological effect.

Remember, what do athletes want? They want two things, athletes. First of all, they want to be playing on an even field, and they also want an edge over the other athletes, which is a contradiction, all right? So the question is, how do they get the edge? Can the edge be through training, through nutrition, through pharmaceuticals, OK? How far do you go?

So they want everybody to say, OK, even playing field except for me because I want a little bit of an edge. So that's what we're discussing here today. OK, now do you have any questions so far just on this introduction in here, on ATP? Is there a cycling period with the creatine, where you'll go on for four weeks, off for four weeks.

I think some of the athletes do that. No one has come up with one type of program that says you're on for four weeks, you're off for four weeks, you're on for four weeks. But let's keep in mind the side effects.

Let's take an athlete, let's take a soccer player who wants to get bigger. It might make sense for that athlete then to postseason, if they're looking to get bigger and stronger, using creatine monohydrate for four to eight weeks and then coming off. But would you want them to have it during season when they're running six, seven miles a day and they're practicing and they might suffer from dehydration or do you want to start having problems with GI distress? So you could see where they'd be almost a natural cycling to that if you go along with what the research has been saying.

OK, cellular oxidation. OK? What this is, when we talk about cellular oxidation-- can't even say it. Let me try that again. Cellular oxidation, OK? What we're really looking at is the oxidation of hydrogen. It's the oxidation of hydrogen and the transfer of electrons that is going to end up helping us accept, when we talk about electron transport, we have to accept the oxygen which allows the energy reactions to keep going.

If you don't have oxygen, the hydrogen ends up going onto the pyruvate. And what is produced? Lactate. And if lactate is produced, that will start slowing down, now you start having lactic acid. So this is an electron transport system which helps transfer these electrons down the chain and allows the energy reactions to keep going.

Now, if we look at the electron transport, with the electron transport in here, we'll see that two of the key factors are NAD and FAD. NAD, nicotinamide adenine dinucleotide. So NAD would be fine. But nicotinamide? What will be the main component of that? Niacin.

The FAD, which is an important component also, these are the components, the coenzymes that are accepting the electrons, is flavin or riboflavin. So FAD, the key factor is riboflavin. And I bring this up is because generally, we talk about the B vitamins as being very important for the production of energy. And if you don't have these vitamins, you're not going to be as efficient in producing your energy.

So you can see how you can pick out little things here and there. OK, I'm going to supplement with the niacin, I'm going to supplement with the riboflavin, OK? So you may fill in one weakness. The problem with nutritional supplementation is you can have a weakness anywhere down the line. How do you know that you're hitting all the weaknesses?

So you can do all of this and you still may have maybe a cytochrome deficiency. So you still have a problem with electron transport down the line. So we have the electron transport in there, OK? We have oxidative phosphorylation. Oxidative phosphorylation is how the ATP is actually synthesized.

You have the electron transport, which is to help oxidize the hydrogen. Then that energy is used to synthesize the ATP. This is all part of the same process. So as you're doing this, we're talking about oxidation reduction. You remember that from chemistry? The oxidation reduction, you can't have one without the other.

So there is a certain amount of oxidative stress. When we talk about the oxidation of hydrogen, we're talking about free electrons. And sometimes, these electrons attach to other compounds. And when they do, what do you end up with? Free radicals, OK? Oxidative stress with exercise will produce free radicals.

Now, free radicals is being thrown about a lot. Free radicals are responsible for most of the problems with the world, OK? Free radicals may be involved in aging, they may be behind cancer. They're usually behind bad relationships. Some of the Mid-east conflict, free radicals.

Free radicals is something we used to think about in the '60s. The hippies were free radicals, all right? It has totally changed now. So when we talk about free radicals, we talk about antioxidants. So all of the supplementation with antioxidants revolve around free radicals and the ability to reduce them, OK?

I put in your notes, you can see the production of free radicals causes cellular damage when the free radicals react with a phospholipid bio layer of the cellular membrane. Now, interestingly enough, someone who is working out will produce at least three times the amount of free radicals that a sedentary person will. In fact 3% to 5% of the oxygen used in exercise are going to produce free radicals, OK?

So when we look at some of these antioxidant supplements, here are just some of them and we'll go through this. For example, vitamin C and vitamin E are two of the supplements that have had pretty good research done on them as antioxidants. Now, the research is unclear.

What's interesting is that the research values that are used for supplementation are so far different than what the RDA is. For example, if we look at vitamin C, what's the RDA in vitamin C? About 60 milligrams? And there are many people who say, well, you can go up to-- I mean, Linus Pauling, some of his original work-- up to five grams easy. Five grams. He went higher.

I saw once again with diseases, they were using AIDS patients. They were using intravenous vitamin C at 10 to 15 grams and getting some very good results. So vitamin C is one possible antioxidant. Vitamin E is another possible antioxidant.

Now, vitamin E, I think they advocate eight to 10 milligrams, somewhere in there per day. Now, what you'll have to note is, because once again, we're talking about milligrams where what is the usual supplementation? Usually international units.

So when we look at vitamin E, they're usually supplemented in international units. Now, a milligram in just a pure food source would equal about 1.5 units if it's a pure food source. But generally, the supplements are not pure. So generally, you can make an even one to one transfer, one milligram to one unit of supplementation. And that is on the vitamin E.

And on those, you'll see recommendations on people using vitamin E anywhere from 100 to 400, going as high as 2000. And there's some research that backs it up, then there's research that says, no, it doesn't seem to matter. In general, one of the things we'd note, though, is you don't see any real side effects unless you start going to the research that supplements more than 800 units. So when you look at a daily supplement of 400 units, there's been nothing that shows any kind of side effects or any kind of problems with that.

Superoxide dismutase, SOD. OK, you can see in this case, if you have a manganese deficiency, you get a decrease in the manganese superoxide dismutase activity, and myocardial tissue is more sensitive to damage. So sometimes, it's a combination of the antioxidant and maybe some specific minerals.

A lot of people don't often talk about the deficiency we have in minerals. I would put forth to you that you probably have a greater deficiency in minerals than you do in vitamins. Why? Because you may think you have a great diet, but a lot of the vegetables that we might be eating can be grown in mineral deficient fields. So you may not be getting what you think you're getting.

But many more people, I think, are looking at vitamins. I just was listening to, at homecoming, to Dr Pins. And the research indicates that almost 100% of people are deficient in vitamin D. Almost 100% of people seem to have a deficiency in vitamin D.

When they did supplementation on it, a lot of people, particularly with fibromyalgia, their symptoms decreased, inflammation decreases. OK? And that's one of the problems. That's one of the reasons why, in my practice, I don't give nutritional advice because there's just so much out there and I don't have enough expertise. All right? So I focus more on the exercise portion, OK?

Catalase glutathione peroxidase. The reason why I mentioned these particular antioxidants is because there's a whole list. I mean, literally you can put on hundreds. These are some that I picked out of some of the magazines that are advertising, some of the magazines that the high school athletes are reading. They're advertising these particular enzymes.

And these enzymes are naturally produced in the body. With exercise, you produce more free radicals. Well, that might seem, you know, as a risk, except for the fact that, in response, our body actually increases production of our natural antioxidants. That's why the effects of exercise seem to be beneficial in terms of disease prevention. We seem to be producing more antioxidants than we would normally have in a relative value.

So if you really want antioxidants, exercise, OK? Supplementation, I think, really plays a part in the fact of when you have a deficient diet, as opposed to a good diet and then supplementing. Now, I think there are definitely cases where the supplementation will help. There might be certain components that we don't get in our regular diet.

Pycnogenol. I threw that in, once again, just because it's a favorite of mine. It's the component of red wine. They were selling pycnogenol, it was kind of the extract underneath the grape skin, OK? Interestingly enough is that if you talk about the fruit, a lot of times, you can actually get better nutrition from the juices as opposed to just eating the fruit because you get so much higher concentration of antioxidants.

But they found pycnogenol was one of those substances that if you did not have the grape skin in, you may not get the antioxidant. Now, an interesting thing, when we talk about herbal supplements and antioxidants, how are we coming up with these? Where's the information coming?

When we talk about all these possible pharmaceuticals, cancer curing, a lot of them are coming from places like rainforests. You know, you read often about rainforests. Now, when I was still in New York, I took a course in herbal supplements at the Bronx Botanical Gardens. Sounds almost like an oxymoron, the Bronx having botanical gardens.

However, it has the second biggest herbarium in North America, in the Bronx Botanic Gardens. And they have some incredible research. So I got a chance to take some coursework, and when I talked to the researchers, one things I found out is who is actually sponsoring and paying for most of these trips so they can go down and do their research?

It's usually a business interest. One of the things I've found out is, and this is one of things that concerns the researchers, sometimes they'll go down to these areas and they'll find a native plant that the native people use for certain conditions. And they'll use it, but it's a very small part.

It's not an entire bush. It might just be the leaf or it might just be a shoot. But when you do that, if you go down and collect that then, there's usually not enough of it to bring back to the labs to test. So what do they end up doing so they have enough? They bring back the whole plant.

So what you end up getting is, a lot of times what you get tested is an entire plant as opposed to a specific leaf. So when they try to come up with a compound, they're not coming up with the right ratios or the right active factor. And this is one of the problems we see.

So do I think there are natural healing plants out there? Absolutely. Will we ever get to them? I don't know. I remember some of the old women in the Bronx who used to walk around all along the highways and picking dandelions. And they'd take the dandelions home and use them in soups and teas.

So there's a lot there, but generally in our society, we want to take it, we want to put it in a pill, and usually we end up doing toxic levels. Aspirin, the salicylic acid is the active component, which was often used as tree bark. Tree bark tea and tree bark soup gave you the same component.

Now, if you take that acting component and put an aspirin in, it might help, but it also might tear up your stomach, OK? So some of the things we find, the active factors that are very important and very good for us, we may not be able to reproduce. We may have to just get over that idea that we can reproduce some of this stuff.