ICSC Culture Diversity Module 08
ICSC08 _ Section 1_Exercise Physiology
Instructor: Andy Klein
Video Lesson: 01:45:46

Welcome to the first session of Exercise Physiology. Today, in this session, we will be focusing on muscle physiology review, basics of muscle physiology, and our focus, in terms of the practical application, will be strength and conditioning. We will focus more on the strength with this session. On the muscle physiology, if you remember, the basic muscle structure, we talked about the muscle fiber, we talked about the motor unit, the anterior thigh remote neuron in the muscle fibers that it innovates, and we are going to focus a little bit more, primarily on the sarcomere, which is the smallest contractile unit of the skeletal muscle.

Basically, this is the fundamental unit of contraction, when we talk about the muscle. Now, the actin and myosin fibers that we are talking about, we reviewed that. That is taught well in most Physiology classes, but in your Basic Physiology, they often leave out intermediate fibers and some of the larger proteins that are involved in the muscle, which are very important to us, and then we are going to discuss z-disc streaming.

We can see our basic muscle in here. There is nothing new. Now, keep in mind, the myofibril is really where everything takes place when we talk about increasing the cross-sectional area of the muscle, when we look at the myofibril. This is where we are going to incorporate the protein where the satellite cells get activated.

Keep in mind, in the human, when we talk about increasing muscle size and muscle strength, it is about increasing the size of the fibers, hypertrophy and not hyperplasia, no indication of any hyperplasia at all. Some animals do, I believe the cat and the quail, they can get stronger with hyperplasia, but not humans.

The basic Sliding Filament Theory, this started in the 50s and it is still going strong. There has been some talk about changing the paradigm, and one of the reasons why is when we look at the contractions between the myosin-actin, you can stretch past it where you can, pretty much, it looks you are gapping some of these filaments, but you are not because some of the intermediate fibers are going to be there. We are going to focus on some of the release of calcium in the sarcoplasmic reticulum, and how that affects us, our treatment of the athletes.

Our basic sarcomere and muscle length, if we look in the middle here, this is the muscle resting length. Technically, you would be able to see that this is where you would think you would have the most potential for your greatest contraction because this is where you have the most potential cross bridging between the actin and myosin. When you are contracted, at this point, what you will notice is that you have already used some of the active cross bridging, so at that point you are really not going to lose some of your ability to contract.

Here, you would think in a lengthened position, "Well, I am going to lose some of my ability to contract, too, because some of the cross bridges have pretty much been separated." The thing about that is when you are doing this Type of separation, now, you are going to start being able to take advantage of some of the elastic components of the muscle and connective tissue.

Here is when we talk about z-disc streaming. Here is your z-disc to z-disc. This is the basic fundamental unit. This is your sarcomere. Now, remember, a lot of basic physiology teach about the actin, and the myosin, but you also have a lot of the intermediate fibers. You have nebulin, which often goes with the the actin, and then you have the titin, which often is tracking with the myosin. We will discuss the titin in a little more detail, but this is where when we talk about, "Okay. Let us build a muscle," this is where

the initial damage takes place when we talk about exercise and strengthening. It is this damage which now allows us to incorporate more protein into the myofibril, and this is how we start to get hypertrophy. The process of building muscle is a process of first, tearing down, and then building up stronger.

A lot of our patients, do not understand that the primary goal of exercise is to damage the muscle in a controlled manner. If you go too far, then it becomes an injury, but if you can do it in a controlled manner, then you can build up the muscle. When we damage this z-disc, that is where the inflammation comes in. People often make a judgment, "Oh, inflammation is bad." Not correct. Controlled inflammation is not only necessary; it is a good thing. It is when the inflammation is uncontrolled that we run into problems with the injuries with the athletes, and this process is called z-disc streaming. It is not labelled here, but usually, one of the main fibers that is damaged or the main proteins is desmond, but you also have other proteins like the menin and Simon.

Calpain is one of the enzymes that is activated. Calpain is residing within the myofibrils itself, but when the calcium is released, you will have some calpain activation which helps stimulate some of this inflammation, and this is what will start the repair process. One of the things we have to look, is that when calcium is released, this triggers the muscle contraction, then the calcium is resorbed back into the sarcoplasmic reticulum. If you are fatigued or with injury, this calcium is not all resorbed back and you will have a greater activation. There is a phenomenon that happens that in effect, to try and protect the entire muscle so that you do not have too much damage, you will have some of these contractile filaments contract in order to try and sequester some of this calcium and some of the calpain activation so it does not spread up the entire muscle. Sometimes, you will see this as an inflammatory process. You will see this, called ultrastructural capping. I have seen that term used in some of the literature. Once again, ultrastructural capping. It has not been used a lot, but that will create a cap so that you do not get soreness throughout the entire muscle.

If those filaments are contracting for any period of time, they will start to shorten up. I do not think there is any effect when you talk about one exercise session, but if you talk about repeated exercise sessions, you can start to get some hyperactivity, some contraction of these fibers, and they have to be broken up. When we talk about soft tissue work and myofascial release, and things like that, we still do not have a clear physiological explanation for exactly what we do. We know our athletes will feel better when we do a Type of myofascial release, but we are not sure exactly what is going on. I think the concept of breaking up adhesions has pretty much been shown that we are not sure if that is going on.

If you look at some of Stecco's work on densification of soft tissue, maybe we are doing that. When we do the soft tissue, maybe we are able to loosen up some of the contractions in the muscle which allows better resorption, which allows better recovery time, either that, or maybe it is just the heat that is produced when we do some of what we call myofascial release, or it is the actual pressure, mechanical transduction, which is affecting the cell, but we do not really know. Nevertheless, we do know that soft tissue work is very important for athletes.

I want to bring up this concept, when we talk about titin in here, one of the things we can see is that titin has different forms. I think one of the things that is overlooked is when we talk about some of these proteins, we talk about in relation to, "Okay, this is myosin this is titin," but in fact, there are a number of different isoforms, and titin, which has been studied a lot more in the last five years or so, one of the things we will see is that the titin has different isoforms. You can have different isoforms in the cardiac and skeletal muscle.

If you look at this, this is in the same study, not only can you have a difference in the cardiac and skeletal muscle, but skeletal muscles, themselves, can have different isoforms of titin. When we look at some of this, for example, you can see in the psoas versus the soleus, you will have different contractile abilities in here. Some of our athletes may have different isoforms than other athletes, and what happens is clinically, when an athlete comes into your office and says, "Well, I have always been tight," well, you can probably trust them that, "Yes, they always have been tight and we do not need to over stretch them." We listen to our athletes, but this might be the physiological reason why we see some of the changes. It is not just the muscle, but we can also see difference in the connective tissue structure in a lot of our athletes also.

When we look at the muscle fiber Types, this is a review, the slow twitch versus the fast twitch, Type I versus Type II, if you do not remember this, the classic physiological model that I was taught when I was doing my Masters was just think of the chicken. The chicken is walking around all day so their legs or the dark meat of the chicken, that is because the higher concentrations of myoglobin because they are not doing anything explosive. They are just walking around all day, versus the fast twitch or the white meat, the light meat from the chicken, which they do not really use it every once in a while. They will convulsively flap their wings, and that does not need as much myoglobin. It is just a quick explosion power. Fast twitch Type II would be the white meat or the wings of the chicken.

We look at the slow oxidative Type I versus the fast oxidative/glycolytic Type II. Remember, Type II is Type IIA and Type IIX, which is a change from the last 15, 20 years ago when everybody was talking about Type IIB. Why the change from Type IIB to Type IIX? A lot of it has to do with technology where we are able to identify more myosin-heavy chains and we end up calling it Type IIX. Type IIC is the undifferentiated fiber Type. As you can see, the Type I versus Type II, and this is pretty straightforward, that myosin ATPase would be low in Type I, high in Type II, energy utilization, mitochondria, the color, I think this is pretty straightforward, and the duration, prolonged and short. Just keep in mind, Type IIA has some ability to maintain as contractions for a longer period of time, whereas Type IIX is easily fatigable. This comes into play when we talk about eccentric actions and damage to the muscle fiber, that Type IIX seems to be the vulnerable fiber.

Type IIA fibers, six times greater power and 26% greater cross-sectional area than the Type I fibers. Type IIX fibers have 10 times greater power and 39% greater cross-sectional area than Type I fibers. Once again, you can see it is the Type IIX fibers where we get a lot more of our power, but you still have significant strength and power that are developing in the Type IIA fibers.

The question you will often get is, can you change these fibers? What is the genetic potential? Is there a genetic tendency? This was one of the studies and this has been looked at a lot. I just like this study that was done. When they looked at the effects of endurance, strength, and power training, what they found is you can see the shift from Type IIX to Type IIA and back at about five weeks, depending on your training. If you are doing more of, let us say, Type IIA fibers maybe more speed and endurance, whereas Type IIX, which you would do in just intense sets of one or two repetitions, that would be the difference in training, there is a very limited body of evidence that suggests that you may be able to shift between fast and slow fibers.

In terms of your athletes, when we talk about genetic potential, if we talk about a muscle, we sometimes say, "Oh, that is a Type I muscle. It is more of a slower muscle or postural muscle," that does not mean it is all Type I fibers. It might be 70% Type I and 30% Type 2. That will be different in certain people. What we are seeing is some of our elite endurance athletes, some of these muscles are 90% Type I and 10% Type II, so they are built for endurance. They are built for these extreme-type of events where you will see some strength people when we talk about Type I and Type II, in Type 2 muscle, let us talk about, maybe, a gluteal muscle, Type 2 muscle, well, that will be different in some athletes. That might be a

60/40 split, 60% Type II, 40% Type I. In some athletes, that could be a 70% to 80% Type II and 20% Type I, so you can see, they have a greater potential, then, for increased strength and increased hypertrophy.

When we talk about repairing the muscle and we are talking about strength conditioning, satellite cell activation is necessary for hypertrophy. This is just a simple chart. What will happen is the muscle will be damaged. There is going to be a difference between whether it is damaged from exercise or whether it is more of a serious injury. One of the things that we are looking at is the satellite cells, which are in the basal lamina of the fiber, they will start going but they will also split and reproduce so that you have a continuous, steady pool of satellite cells in the basal lamina, and then they will go in here. Now, one of the things that is interesting, this occurs with exercise when we talk about strength and conditioning, you will damage the fibers a little bit, but the satellite cells are not designed just to patch the area. The satellite cells are designed to patch the area, but also incorporate more protein, and that is how we get stronger.

I saw at least one study at the University of Utah where they talked about the satellite cells and how it coordinates with the fibroblast in the cells to help produce, repair the muscle, incorporate more protein, but at the same time, the fibroblast, producing more collagen to help with the synthesis and the healing and the increase of connective tissue. Remember, you will get an increase in collagen weight with strength conditioning in your ligaments. They did animal studies, but what they did is they ablated the supply of fibroblast in the area to see what the effect was on the satellite cells. What happens is the satellite cells ended up reproducing what they were activated prematurely, so the muscle fibers that they produced, in effect, were damaged, they were random, and much weaker. They also did the opposite where they ablated the satellite cell pool. What they found is the fibroblast then ended up having to work harder, but they produced a connective tissue that was weaker, so it appears as some sort of signaling in the cell between the satellite cells and the fibroblast so that we get an increase in the repair of the muscle fibers and the connective tissue, at the same time.

Keep in mind, in this area, you will see some bleeding. This initial framework or matrix so the cells can lay down more protein, initially, is a fibrin clot, fibrin threads. They are somewhat fragile for the first 24 to 48 hours so you have to be careful about applying too much stress to these areas on a consistent basis, that we have to make sure that what we are doing when we do this is we are still protecting the area. That is why, sometimes, heavy-light day or even on the heavy days is not damaging the muscle too much.

Here is an example of some of the changes you will see. This is what we have, a young athlete with a great supply of the stem and satellite cells. You will get the activation; the athlete does their work out; they will do some strength training and they will get the injury in here. Then the stem cells just come and do their job, but as we get older, our supply of stem and satellite cells are not as good. When we are talking with our older athletes, especially when we have an older recreational athletes or our masters athletes, they may need a little more time to heal, whereas in the younger athletes, they can go heavy day, heavy day, heavy day, then maybe a light day, so that can vary. Our older athletes now become, maybe, instead of heavy day, light day, heavy day light day, becomes heavy day light day, light day, heavy day, or maybe you need more, like three or four days of lighter activity to help with the recovery.

You also can see that the environment of the satellite, themselves, the local microenvironment can be damaged or at least not satisfactory for the rehab process. We are talking about, dehydration, poor nutrition, all which can also affect the stem cells/satellite cells.

Looking at some of the studies that we have seen on the satellite cell, Sir Mac looked at a single bout of high force eccentric exercise, it increased the muscle fiber satellite cell content and activation status in Type II, but not Type I muscle fibers. We can see that the type of exercise session that you do will have

an effect on different muscle types and different areas of the muscle. This change that we saw occurred within 24 hours post-exercise recovery. A single session will automatically start having an effect on the satellite cells. Usually, a lot of the satellite cell activation appears to occur maybe within 2 hours or so.

High-intensity resistance training at a normal speed resulted in significant fiber type-specific adaptations, that is the increased MMD. MMD is myonuclear domain. This is the cytoplasmic volume within the myonucleus, and this is an indication of a better response to training. It gives you an idea that high intensity is always better than the low intensity, no matter what the speed is. I think we will see this in a several different situations and a several different studies, how important high intensity is.

If you are really talking about strain conditioning you have to go heavy. You must go higher intensity.

A high-intensity resistance training protocol, about 85% of your one rep max, will yield the greatest overall adaptive response within the skeletal muscle fiber. This study by Herman-Montemayor, shows you just how important the intensity is.

It says "about 85%", and that is going to vary depending on your athletes. When we talk about the strength power curve and how do you get the most of it, the most out of your workouts, you will see that it will vary from athlete to athlete and you will almost have to keep track. It could take you six months to a year to sometimes figure out what is the best exercise training session for that particular athlete.

Eccentric overload during leg extension exercise, once again, a single bout, induced significant satellite cell Activation and content increases. Satellite cell numbers related to Type II myofibers occurred within 24 hours post-exercise recovery. This is a confirmation with what we have seen. This research has came out this past year.

Interestingly, there were no signs of increased satellite cell differentiation or formation of new myofibers within the first 24 hours. The formation of new myofibers and the satellite cell differentiation probably occurs at a later time period. We have to look at, this is a single bout of exercise which shows you the change we have, but it is a cumulative effect that seems to give us the changes in satellite cell differentiation and the formation of the new fibers.

Satellite cell number activation and myogenic potential are modulated in different physiological and pathophysiological context. What that means is when we talk about the continuum, the spectrum of exercise, with exercise, we are trying to create an injury, we are trying to create damage but in a controlled fashion, but if you go too far along this continuum, that becomes injury, and then the body responds differently.

When we look at the injury, one of the things we see is a local transient fibronectin secretion by satellite cells, very important step in the cascade of satellite cell activation, and an increase in the fibronectin in the muscle. It is necessary for successful regeneration. Remember, fibronectin is an acute phase protein. It is almost like a natural-type glue for the cell, so very important, but if you have too much of the fibronectin in the basal lamina in the under injured state, this is correlated with a reduced ability of satellite cells to respond to injury. Who would have an excess fibronectin in the basal lamina? People who are untrained, who are sedentary, or overweight. We can see that the body has a homeostasis that it has to try and maintain, and a lot of the increases we see in terms of fibronectin interleukin-6 and things like that, these are transient increases. If you have higher levels of this because you are centered on untrained state, this will actually interfere with your ability to get stronger with your ability to repair the muscle when you try and do training. People who are first starting out, if they have been sedentary for a while and they just, they want to get back into it, let us say you have a patient who is once an athlete and they have not worked out for 10 years, they have not done any training, they get back in,

they are not going to have the same response to training as an athlete who has maintained that training over a period of time. It is going to take a little bit longer and they must be a little more careful. This is where we talk about recovery, where they are getting to need a little more recovery maybe than they did if they had been training the entire time.

Delayed onset muscle soreness, very important. DOMS, we see this often. Exercise-related muscle pain that develops after excessive and unaccustomed exercise, it more commonly occurs with eccentric exercise. What we will see in a lot of cases, a lot of the damage in our athletes are eccentric-type mechanisms of injury. For example, if you have someone who is throwing overhand, a baseball pitcher, a bowler in cricket, when they talk about the rotator cuff, the rotator cuff damage is due to through an eccentric type of action, trying to slow down the forward motion, the forward acceleration of that arm as it comes forward, eccentric exercise may damage Desmond predominantly and cause an increase in intracellular fibronectin. Once again, we get back to the Desmond, which is at the z-disc. We see that the Desmond, that is the damage, but that is a good damage, that is, kind of, a controlled damage that we are looking for. I will sometimes see this, especially my cross-country runners, who have not been staying in shape because hill running, especially running downhill, there is a strong eccentric component to that so you will see them damage themselves at the beginning of the season if they have not been staying in shape.

It suggested that Type IIX fibers are more vulnerable to glycogen depletion and endurance training may help limit exercise-induced muscle damage, only because it may give them a little bit more resistance to fatigue as you work out. Keep in mind, when we are talking about these big muscles that are primarily Type II fibers, Type IIA, Type IIX fibers, there are still Type I fibers within the muscle, so if you want to develop the whole muscle, you still have to do, maybe, a little bit of endurance, but you do not want to do so much that you take away from the effect of the Type II fibers.

We are going to look at some of the muscle physiology, the types of muscle action. When I look at the types of muscle action, this is straightforward: concentric, isometric, eccentric.

Presentation Video Placement: 25:16 – Video Playing within presentation

This video is a volleyball player. I want you to watch her do the simple squat. Holding it there, she is in an isometric position. As she drops down, you are going to see that eccentric axes so her core will stay isometrically stable, her quads will go down and control eccentrically. As she goes down, she is going to hit that bottom position, and she must get that hip extension, then the glutes are going to have to fire, but they going to fire more in a concentric manner.

At any point, depending on the type of training, you can accentuate what you want. For example, there is someone at the University of Minnesota, Cal Dietz, who coined the phrase, "triphasic training", and you can work on it. For example, let us say you want to work more on the eccentric component, you can go down very slowly to a count of six to eight but you would explode out of it, or you can go down at a normal pace, but at the bottom, hold in an isometric position and then explode out of that, or you can just go very quick and try and accentuate the concentric.

They are all very important motions. For example, if you look at someone like a soccer player who has to make a cut, well, when they make the cut, their first response when they plant that foot, it becomes an eccentric action to slow down and decelerate the body, then there is a moment before they push off that is all isometric, then they push off, and that is concentric.

You can practice, for example, just practicing your eccentric where you just practice landings and things like that in high speed, just trying to absorb and you can work eccentrically, or you can work more

strength in an isometric, or you can practice concentrically, which is what most people do when you talk about pushing off and triple extension motions.

When we look at the muscle physiology and force production, we can look at the fascicle length or the muscle penation. The penation angle is the angle of the fascicles in relation to the line at the tendon. Basically, we draw a line from origin to insertion. That will give us the penation angle. Fascicle length, usually, if you can increase your fascicle length, which is what you do a little bit with strength training, that tends to increase velocity or speed, whereas muscle penation, if you increase muscle penation, the angle, generally, you increase your ability to produce strength, but that will be a cost to velocity. I have seen baseball pitchers before who get very enamored with weightlifting and really develop those arms and they get very strong, but they lose speed off their fastball because they have diminished their ability to contract at a higher velocity. Some of the physiological factors you can see is there is a neural factor in your ability to contract. When we talk about overriding the Golgi tendon response to try and inhibit tension, that is usually done in the motor cortex and pre-loading factors which we will talk about, but ultimately, when we talk about the ability to contract, it comes down to increasing the cross-sectional area of the muscle. You increase the cross-sectional area of the muscle, you increase the ability to contract the muscle, it does not mean you will get all that contraction out of there, then that becomes training and neural factors.

Once again, you can see the different penation, you can have parallel. The smaller cross-sectional, smaller force, longer length, you can get a little bit better, more mobility, the more flexibility, a little bit of a quicker contraction versus the penate. The short length, you get a small length change, but you are going to increase your ability to create a contraction.

When we look at the muscle physiology, high force, low-velocity training, this will increase the cross-sectional area of the muscle, the fascicle length, and the angle of penation, but what you will end up doing with high force, low-velocity training is that is what you are going to develop. Think of someone who might be doing deadlifting, very high force but low velocity, they are going to get very strong, but it does not mean that they are going to get very fast, it is totally different, versus doing a low force, high-velocity training, where you do not get as much change in cross sectional area.

I will not say no change, but not as much change, and increase in fascicle length and a decrease in angle penation. This leads you more to a higher rate of contraction or high velocity, greater speed. What would the ideal be? The ideal thing to train would be high force with high velocity training. There is a trade of the higher the force, the lower the velocity, but if you can hit that sweet spot between the high force and the high velocity training, that is what we are really trying to do for our athletes.

Here is our force-velocity curve. This is what I was talking about. This is the increase in force right here. As you increase the velocity, you are going to find that you have the amount of force you can use goes down, but you can see the continuum. If I want maximal strength, I am going to do high force, maybe it will lower speed. If I want to get a little more in that strength speed continuum where I am still doing strength but maybe add a little bit of speed, now, I am dropping the weight down again until I go totally into the speed. This is our force-velocity curve. Generally, if we want to develop for athletes' power, remember, this is force-velocity, it is not power, we want to develop power, we are generally going to be somewhere in this area in here.

Here is our power-force curve, right in here. What we will find is the greatest power output is right about here, and this will vary from athlete to athlete. You will see it might be working. It is anywhere from 30& to 70%, which is a very large range, so that is why a lot of times, it is determined by observation. It is determined by the history of the athlete where they can develop the most power. If we talk about powerlifting, and this is a term, for example, powerlifting that really is not power because powerlifting,

if you ask most people, and in competition, powerlifting is the bench press, the deadlift, and the squat, those are the three powerlifts, but if you are moving the bar, it is a good lift, even if you are moving it slowly. You are using that high force, but a very slow velocity. On this force, velocity curve is changed in here. As we increase the force, you can see the velocity of shortening has dropped down, so you are not going to get as much power as you would like.

Once again, we are looking at the cross-sectional area of the muscle in here, so we are going to increase. Remember, the number of fibers does not increase. That is hyperplasia. We do not have that. What we have is an increase in the volume or hypertrophy of the myofibers, which leads to an increase in the cross-sectional area of the muscle. The number of force generating sarcomeres arranged in parallel predict the maximum force-generating capability. Sometimes, you will see this term is PCSA, physiological cross-sectional area, these are the same things.

Your fundamental principles of muscle contraction: The peak rate of contraction, it is dependent on the myosin ATPase activity and the size of the motoneuron. We will get into the size principle. Maximal force is dependent on the actin-myosin action, the ability to make that contraction repeatedly. Continuation of the contraction is dependent on the ability to recycle ATP, so then, you are getting into your bioenergetics. How good is your ATP-creatine phosphate reservoir? How good are your enzymes, which allow this metabolic action to occur? Muscle fatigue is the decrease in the ability of a muscle to generate force. Now, this can take place at the muscle itself or this can be more of a neural change. You can have peripheral fatigue in the muscle, you can have central fatigue in the nervous system.

Let us look at our velocity of shortening, our force-velocity curve for eccentric and concentric actions.This point here, joint angular velocity is 0. That is our isometric hold right in there. As we start to contract, as the muscle shortens, that is our concentric action, you can see you have more strength in the flexors than you do in the extensors. As you increase the velocity, the ability to create strength goes down. Now in the eccentric mode, you can see, once again, flexors a little stronger at the knee than the extensors, but if you look in here, you can see eccentrically at a small level, if you are not going too fast, you can actually increase the most force in that eccentric manner. That is when we talk about possibly doing what we call negatives or eccentric work to get some strength. If they are having trouble lifting and they have hit maybe a sticking point where they cannot go heavier, it is a good idea to develop more force in the muscle to develop more capability of muscle to start doing some eccentric training.

This is, in the gym, what is it called, using negatives and weight training. Let us say this is 100 kilos or approximately 220 pounds. They cannot go any further so you can put more weight on, and then they can control it going down, and then their training partner helps them bring it back up. That is a way of breaking through that platform. Keep in mind, eccentric training is tough to do. It will create more soreness, especially for someone who is not used to it. In most training sessions, there is an eccentric component if you are controlling the weight, but if you want to take advantage of that peak in strength, then you have to go to an eccentric level that you cannot lift concentrically, and that is why you need a training partner or you need some sort of adaptation.

Where can we get the most strength in the sarcomere? If I review, it looks like it should take place in the natural, the resting length in here, because that is where you have the most potential for cross bridging. As you contract, you have already used the potential, so in a short muscle, you will not have as much ability. In the length and muscle, yes, this is the area where you have the most contractile ability. Even though you lose some of the contractile ability of the cross bridging, you will get that back as the muscle starts to shorten. You are getting a greater boost from the elasticity of the connective tissue in the muscle. Remember, even though it looks like this is separating, you still have titin, which has a huge elastic component. That titin is going to help bring that muscle into a shortened position to help improve the contractile ability.

This is the length and position, and that is this part of the curve right in here. That is where you get that eccentric component. Here is your resting length of the isometric, and here is your shortened position, so you can see, once again, this is where you have that decrease in your ability to contract.

With muscle proprioceptors, when we talk about training stimulation, stretch reflex is a muscle contraction response to stretching the muscle. That is pretty basic. When a muscle lengthens, the muscle spindle is stretched, and its nerve activity increases. When we talk about the stretch reflex, about plyometrics, about jumping, this is what we must keep in mind.

The Golgi tendon organs that you are familiar with, they connect extra fuel fibers and detect tension, not length changes. When you are training, the Golgi tendon organs are trying to inhibit your ability to produce this tension as protective device. This is going to be over in training. It will override the Golgi tendon organ so you can produce greater tension. That override is going to take place in the motor cortex. The central nervous system is going to override what is happening at the local level so that you can increase. This is what some of the training changes that we talked about with strength and conditioning, and we talked about nervous system changes, also.

The Pacinian corpuscles, located close to Golgi tendon organs, this is sensitive to quick movement and deep pressure. When I talk to students, I always tell them, "This is one of the reasons why when you are doing soft tissue type of techniques, go light and gradually increase the pressure". "If you go too deep, too quickly, or apply too much pressure too quickly, the body is going to fight that. The body is going to respond by tightening up. If you give the corpuscles a chance to adapt to feel the pressure, you can actually start going deeper into the tissue without getting a reactive rigidity from the patient."

Looking at the elasticity of the muscle and connective tissue, we look at the stretch reflex, so we drop down. If we look at a countermovement jump, this is what we are talking about. You drop down, you stretch the muscles to get a good connective tissue stretch and a muscle stretch and you can use that elasticity to help with the muscle contraction. This is a countermovement jump. In this case, if you want to, this is how you can measure vertical jump in an athlete. If you do not have any fancy equipment, you could just do this on a wall. You put a little bit of chalk on their fingertips and have them just right there and measure that, then you have them jump, and you can measure from chalk line to chalk line from their fingertips and that gives you a vertical jump. Very important to get the vertical jump. Jump mats can work, but there is an equation that you need to make sure that you get a valid and reliable reading.

A lot of sports, when they talk about combines and pre-season training, they will use different type of jumps to measure vertical jumps. You must make sure if someone is talking about what their vertical jump is, you have to find out, "What type of vertical jump did you use?" In the NBA, this is a countermovement jump, they also do what they call a maximal jump, where an athlete is allowed to take two or three steps and then a jump.

Some of our neuromuscular adaptations, we talk about the all-or-none law, twitch versus tetanus. We are trying to get that increase, and this is almost a post-activation potentiation where you are going to get a little bit of a jump and then if you do a quick relation, then do the next contraction, you can start increasing the amount of tension that you have. If you apply too much, if you keep going, it can become like a tetanus or a cramping-type situation.

When we talk about the muscle contracts, we talk about gradation of force. If you want to increase the contraction of the muscle, you can either do it by rate coding, which is frequency of activation, so the motor units activate at a faster rate, or you can talk about recruitment, which is the number of motor units that are actually activated. Now, what is interesting is if we look at gradation of force, we can see

the different types of muscle fiber. In the Type I fibers, which is more of an endurance fiber, when you start increasing the intensity of the exercise in Type I, you are going to get increased recruitment to 50% of your maximum voluntary contraction, and then it becomes rate coding. When we talk about Type I fiber, let us talk about, maybe, the small muscles in the in the low back, for example, if you want to do some stabilization exercises. At a little lighter intensity, you can get every one of these motor units to fire at 50% of your maximum voluntary contraction.

If you want to just have them start increasing their frequency, then you can go and increase the intensity, and then it becomes rate coding. You do not need heavy weights or heavy loads to get all the Type I fibers to fire. However, in Type II fibers, what you will notice is that at the initial contraction, what you will have been that with the lower weight, you will have a pool of fibers that will fire to 10% of your maximum voluntary contraction. As you start increasing the load, you will start increasing your recruitment. As you increase your load up to 90% of maximum voluntary contraction, that is how you will get the recruitment. You cannot get full recruitment of Type II fibers until you get into heavy loads, almost 100%. Basically, 90%, if you want to get all those fibers to fire, you must lift heavy, you have to increase the load. The last 10%, you will get great coding.

That tells you, in terms of training for the athletes, once again, it is all about intensity. Most athletes know this, that they need to go 80% to 90% of their maximum voluntary contraction if they really want to get improvement of their strength.

Once again, what type of strength are we even talking about? What kind of strength do you want? We are talking about endurance. Here is, I believe, a 50K runner, or do you want to be able to lift tires? The ability to lift this tire, I am not sure how applicable that is to everyday situations. I am not sure how many athletes we have who do this, but it is a great strength training. A lot of people say, "Well, is this even applicable? What are you doing?" Well, it is a great triple extension, but sometimes, more than that, for the athletes, it is fun. If it is fun, you are going to get a psychological stimulation in there, which really is quite important also.

Our firing pattern is based on the Size principle. This used to be known as the Henneman's size principle, but I know there has been a move in scientific circles to try and get rid of names as much and just work with the physiological principles. As muscle force increases, motor neurons with progressively larger motor axons fire. Neuromuscular fatigue. There is a decrease in muscle tension with repeated stimulation of the muscle fiber. Once again, depending on your training, if you are training more, then you are going to help decrease this fatigue factor.

Here is your firing pattern. Force production, low versus high, recruitment threshold. Here is the interesting thing. In some of these exercises, you can have to determine, for example, if you are doing a deadlift, if you are a working at light weights too much before you get to the heavy weights to get the strength and power, you might end up almost fatiguing out your grip muscles, your forearm muscles before you really get into the type of strength and load you need to stimulate low back and legs. For example, a squat works very well because you are really not going to fatigue the small muscles, and the squat works very well if you can handle the compressive forces.

Once again, we want to talk about some of the neurological responses. Neural plasticity can occur within the primary cortex in response to motor training. There is a greater number of synapses per pyramidal neuron in the motor cortex when complicated movements are practiced compared to simple tasks. Now, this was an animal study, a rat study. I was always fascinated by the fact of exactly what is a simple test compared to a complicated test to a rat. I was not sure. I was introduced to a PhD in Neurophysiology at a bar one night. She explained to me, that it is just based on the test, so the question becomes, "If I complicate the test, I can get a better response to training, but what is too complicated?" For example,

if I am on a balance board and I am trying to juggle different medicine balls, maybe different weights, is that too complicated? Will that end up complicating the process? No one really knows, but I will say that this probably is one of the reasons why when we combine some of these balance with catch exercise or balance with strength training, why we might get a better response.

In terms of neuroplasticity, new exercises, in general, will increase your response in the primary motor cortex. That is why we constantly want to introduce new exercise, which may not seem like they have a lot of sport specificity but can still be very helpful. In general, when we talk about our athletes, remember, most of the environment that they are dealing with, if we talk about a soccer player, basketball player, or a hockey player, they must respond to unpredictable situations. The perfect motor pattern is not always going to be available to them, and that is why the more different exercises they can do, the more different angles, that neural stimulation is only going to be helpful in the long run.

If we look at this chart, for example, what are the training adaptations, we see them with resistance and endurance exercise, the fiber size and resistance will increase endurance, not so much the number of fibers. Remember, number fibers do not change whether you are doing resistance or endurance training. Your movement speed will increase with resistance, not necessarily with endurance. Your endurance, obviously, straightforward, will increase, but what is interesting is you can get some increased endurance with resistance training. You can get some increase in maximum VO2 with interval-type training. Your strength will increase with resistance, not so much with endurance. Your aerobic capacity, obviously, will increase more with endurance training than it with resistance training.

We want to look at strength and a lot of people have different definitions. Do not think that everybody agrees with exactly what strength is. I like the idea of the ability to transfer strength to sports performance is what is important. Now, this principle of dynamic correspondence, and this is from Siff and Verkhoshansky, the ability to use the means of special strength preparation that corresponds to the functioning of the neuromuscular system in any given sport. Not everyone agrees with this, some people will say, "Just get as strong as possible and then with your regular training sessions, you will be able to incorporate that into your training." Siff and Verkhoshansky believe that you can do things that are a little more specific to you sport, which will help at a greater rate. I think one of the things to keep in mind is if you are one of those people, "Let me just do the strength," and then incorporate into their sport, you have to be careful because a lot of these sports are specific motor skills.

If you are talking about throwing a ball, for example, it is a skill. If you got too strong, you could interfere with that motor skill. I think one of the things you can do is you can get stronger during the offseason, for example, make sure you still incorporate that into the sport. For example, our basketball players, when we used to do during the offseason, we would want to increase their vertical jump, have them get stronger, we would still make sure that they practiced during this strength conditioning period so as they were getting stronger, they were able to incorporate this strength in a gradual level into the motor skill, so that we did not end up interfering with the motor skill.

You can be sport specific. For example, if you are doing plyometrics for a basketball player and you want to increase the jump, keep in mind, you can actually do plyometrics with a ball in the hand, where maybe they are doing box jumps, but when they jump off the box with a basketball in their hand and then they jump up, there is a big difference between jumping to touch a rim versus jumping with the ball in your hands to reach the rim. There are different things you can do. I am not going to tell you there is one way of doing it. If there was one specific way of doing it, everyone would do it. The fact that there are so many different systems tells you that, we do not really know.

Rate of force development is a term that you must be familiar with, and this is basically "explosive muscle strength". If you have strength how quickly can you use it to develop the force so you can push off or you can jump? Power is the amount of force exerted through a certain distance per unit of time. This is what we really want. I do want strength, but we want power. Peak power is defined as the highest power value achieved during the task being performed. Power equals force times velocity, and we already talked about the inverse relationship between force and velocity.

This is the curve that we looked at, the force-velocity curve, and there, you can see the inverse relationship which is an interesting chart because this gives you an idea of, for example, what percentage of your one rep max should you be working at? Maximal strength you absolutely must go up to 90% to 100%. Maximum speed is less than 30% of one rep max. Here is your peak power range, 30% to 80%, this is what I was talking about is it is going to vary. Some people are using something called velocity training and they will put an accelerometer on the bar, for example, when they train. They will try and determine; at what speed can they lift the most weight and where they get the best power equation when they do this? This will vary. What you must do, though, is you just must follow an athlete, because athletes will fall somewhere in this range, but they are not all going to fall in the same position.

If you look, this is a chart of sprinters, Ben Johnson, Carl Lewis, Maurice Greene, Tim Montgomery, Asafa Powell, and Usain Bolt. What you are seeing is their ground contact time. Remember, at the very start, that ground contact time is larger. Why? Because they must overcome inertia so that they would produce more force, but once they get going, whoever can hit the ground and get off quicker, that is going to be the fastest runner. You can see in here; you can see the difference between Bolt and the other runners. At 50 meters, he was hitting the ground and pushing off.

You lose a little bit of force production in here because you are not on the ground as long, but this was his sweet spot right here, where he combined that combination of production and speed. That is the power zone for him and look how much quicker he was from 50 to 90 than all the other runners. Also, in here, he slowed down a little bit but that is because he is usually winning in the last 10 meters anyway, but he was still getting great force production, but this is where he was winning his races, especially in that 50 to 90-meter range.

This is the sprint that is coming up. I want to show you this because in here, when we talk about exercise and strength in sports, this position here is that triple extension position where they are pushing off. It is extension of the ankle, the knee, and the hip, triple extension. In a lot of our weightlifting, this is what it is focused on. What is very important, though, in this position here is the triple flexion position, which is just as important, a little bit harder to train. The triple flexion position is flexion of the hip, flexion of the knee, and flexion of the ankle, or dorsiflexion, basically. A lot of people forget about this part of the training in here. Very important to develop this strength also, as well as the triple extension strength for pushing off.

When you are training athletes, keep this in mind. With untrained athlete, strength training will result in significant improvements in power. It really does not matter what you do. As long as you give them some training, they will improve. Athletes with established strength levels are higher level or elite athletes. They are the ones who really will benefit the most from specific training, dynamic lifts, snatch, clean, and jerk, and plyometrics. That is how you are going to optimize their power development.

Let us look at another exercise here. We go back to our volleyball player and using cleans. You would think, "Cleans for a volleyball player?" Well, clearly, you can see there is the triple extension coming up. What is interesting is this is a setter. This is a Setter who can clean her own body weight easily, very strong, and it improves performance. When you talk about jump sets, when you are talking about the

set, in general, a lot of it is coming from the legs, your ability to get to a ball and do a cross court set, or if you get a bad receive, the ability to overcome that. That all comes from strength and conditioning.

Your basic concepts of strength training. First, overload, this is one of the key things. You have your stimulating loads, especially during the offseason when you are trying to get strong, and then you have your retaining loads, when you are just trying to maintain your strength. There are detraining loads, where you will just try and almost go a little bit lighter. Maybe this is where you decrease your force and maybe increase your speed a little bit, your accommodation to loads. This is very important, the SAID principle, A specific Adaptation to Imposed Demands. You must go as specific as possible. If you really want someone to run faster, the best strength training you can do is have them run faster. I know that sounds simplistic, but how do you get someone to run faster? That is the whole goal. Well, you can have them run downhill at maybe a three or four degree angles, so that will force them to actually go run a little faster. You have your basic concept of individualization, that people are going to respond differently to training and that they will respond differently to different exercises.

Our assignments based on the goal. This is the number of repetitions. There will be some overlap in here, but if you want to develop power, you are looking at one to three repetitions, three to five sets, but you need the three to five minute-period of rest. You must make sure that you have full ATP re-synthesis. You want to make sure that you are not stressing the metabolic pathways, that you are just stressing the structure of the muscle. Now, with strength training, you are talking about six repetitions or less for three to five sets, but you still need that increased rest period. This is where we fall off because this does not become valuable. A lot of coaches say, "I only have this much time, I cannot afford this amount of rest." This is the amount of rest you need in between sets if you want to get the most benefit out of this training goal. For hypertrophy or just trying to get a little bit more volume, this will almost be a basic conditioning concept, six to twelve repetitions, three to six sets, 30 to 90 seconds. Endurance training, 12 or greater reps, two to three sets, 30 seconds or less rest.

I would tell you that when it comes to the hypertrophy or basic conditioning, generally, you really do not need six sets. The amount of improvement you will get from three to six sets may not be worth the amount of time that you put in with the athlete. That is something that must be decided with the athlete in terms of efficiency of training. For power and strength, I really find that the four and five sets will make a difference. I am not sure for your general conditioning where the six sets are going to be that great of an improvement that will affirm that you should be doing it. It is almost you will probably get as much benefit for three to four sets in terms of time and that putting in that extra time, really, is not an efficient way of training.

Before we get into some of the lifting, let us make sure we review our biomechanics resistance exercise. We have a first-class lever where the muscle force in the resistive force act on opposite sides of the fulcrum. We will call this the moment arm, moment of gravity, gravity is pulling the head down. Here is your moment arm of the muscle. Just keep in mind, when we talk about someone with the forward head posture, the head is moving forward so your moment arm of gravity will get increased. The moment arm of the muscle will not change, and that is where we talked about how the head will impart more force. You will have to work harder in the cervical muscles with a forward head posture.

The second class lever, this is where the muscle force and the resistive force act on the same side of the fulcrum, where the moment arm in the muscle being greater than the moment arm in the resistance. When we are going up on our toes, here is our fulcrum, center of gravity is coming here. The moment arm of the resistance or gravity is shorter than the moment arm where the muscle is in relation to the fulcrum. Therefore with a relatively small cross-sectional area of a muscle in the calf muscles, we have no problem lifting or exploding and creating a lot of force even though we are not talking about a huge amount of cross-sectional area of the muscle.

The third-class lever. This is how a lot of the muscles in our body work. The muscle force and the resistive force are on the same side of the fulcrum, but now, the moment arm on the resistance is greater than the moment arm in the muscle. Here is our bicep, we are doing a bicep curl. You can see here the great biomechanical disadvantage in the moment arm of the muscle compared to the moment arm of the resistance.

One of the things we do is we try and affect this so we can get a smoother action. This is a cam system. What you see with the cam system is in this position here, you can see the moment arm here, we have no trouble lifting, but right here, this is our greatest biomechanical disadvantage. Often, a lot of people refer to this as the sticking point. If you can get past this point, now, the moment arm decreases so now, you can complete the contraction of the muscle. In effect, to try and get this to be a smoother action, some people will use different levers and different cams. You can see if you are using a cam here, that the moment arm does not change as drastically in this way, so you can probably get a more consistent contraction of the muscle and not have to cheat in here. Look at the difference in moment arm from here to here versus here to here. That is what a lot of these machines try and do. That is what we try and do, even with some of the free weights.

The sticking point is the weakest point in the range of motion of an exercise, which probably occurs where the external resistance has the greatest mechanical advantage. If we go back here for a second, you can see if we use too heavy a weight, we cannot get a complete contraction. If we use too light of a weight, we would not get full stimulation of the muscle.

Let us look at a squat, for example. On times, this bottom position of coming out of the squat is where we are going to be weakest. What you can do is you can alter this with chains, and elastic bands can also be used. What will happen is as he starts dropping down, the change will start dropping down to the ground so you will have less resistance in here. As you start lifting into that stronger position, you will get more chain links, which would now have to be supported. This is how you can use chains or elastic bands to give you a better contraction throughout the movement.

This is a study by Bret Contreras, looking at, are all actions the same when we talk about back extension? Here is a back extension from the good morning position. Here is a back extension from the 45-degree position, and here is the back extension from a horizontal. You can see that it is the same movement, but you are going to get different amounts of force. When you look at what is happening in the good morning, the most force will be at the 90-degree position, but at 180 degrees, basically, you are just resting on the osteoligamentous system. Forty-five-degree back extension, you are producing force throughout the entire range of motion, whereas in the horizontal back extension, you are really getting most of the 180 degrees, but when you are just relaxing, you are not producing any force.

We look at the good morning, and develop the back extension, but you could be developing the most force with the fibers in the longest position relative to the other exercises. This is an excellent exercise for developing back strength, especially if you are trying to supplement deadlifts or any kind of cleaning-type movement in here.

Here, you going to be producing the most force, almost as this 45-degree position, going to here. This is actually a very good exercise when you think of sprinters coming out of a slower position and coming up into an upright position. This might be the exercise that you want to use for sprinters, or just think, for example, anybody coming out of the position, maybe even rugby players who are coming out of this position, you can see, they want to stay very low in there, versus the position where you get the most strength with the muscles in a shortened position. Anybody, for example, patients who have low back

pain when they are standing, this might be the position you want to strengthen them in because they are getting the most development with the muscles in a shortened position.

The specific exercises, snatch, clean and jerk, power clean, hang clean, push press, and push jerk, we will go over these so you can see exactly what we are talking about. When we talk about Olympic weightlifting, that is a redundancy. Weightlifting is just weightlifting. To say "Olympic", that really is something that is not making a lot of sense. We look at these exercises burst, looking at something like these specific size, what we call the powerlifting exercise, the deadlift, the squat, and the bench press. If you are weightlifting, that means you are doing either the clean and jerk or the snatch. It is that simple.

Let us take a look at some of these exercises. First of all, we will look at the snatch and the power snatch. Here is an example of the snatch. You can see just how quick that is. This is how you develop the power, versus you know just doing something slower like a deadlift or a squat. I want to show you, let us just look at this for a second. We will review this is. You can see him getting that, so you need a good amount of flexibility in there. You see where he is catching? He is catching down low. A lot of athletes would catch even lower than that. Catching down low, and he makes it a snatch. If you catch in a higher position, that makes it a power snatch. That would go the same for clean or a power clean. This is where our weightlifters are dropping down to. This is where some of our athletes go to. For example, if you have CrossFit athletes, you will see a lot of what they do is power snatch and power clean. Which is better?

I am not sure if you have to go down this low for most sports. I would tell you, if you can develop your power using power snatch and power clean, that would be excellent for the athlete. I still think you want to work range of motion, but maybe for your athletes, let us say we are talking about a basketball player, I use basketball players a lot because they are taller, they are ganglier, and this could be a very tough lift for them to do, but they could do power snatches or power cleans, and then you can work range of motion in an unloaded position so you can still maintain their mobility and their flexibility.

This is going to be the clean and jerk. This is Dr. Dennis Matos, one of my residents. There is the clean part, and now comes the jerk. You can see on that lift just how much power is developed. I think that was 110 kilos that he lifted, at a body weight of about 83 kilos. That is very good. When we look at it, here, there is the catch, the eccentric strength, and there is triple extension. Now comes the real triple extension and watch the power you have got to do, and then stabilize. This is just a great exercise. If you can do a snatch or clean and jerk, which one do you want athletes to do? The problem is these takes so much time to develop. For example, we look at the snatch, this is a lot of technique. You can see that if someone does not do this right, they can get hurt.

When we talk about basketball players or soccer players, we are going to have them doing something like this, do you really have the time to spend on a technical lift like this? Probably not. You start talking about that risk benefit ratio, and there is a good chance that you are starting to lean more towards the risk than the benefit. I know in this area of Minnesota where I am, a lot of football players, they start doing these lists in middle school and high school. By the time they get to their end year, for example, the volleyball player I showed you, she is doing clean, and jerks and she was doing some snatches, but she started about 9th grade, learning this with a lighter weight. That is how they develop it. I am going to tell you, for most of your athletes, you are probably better off doing just power cleans or power snatches.

Let us look at the clean now. This is a great exercise. I am going to show you the clean, the high pull from a power position, and the power clean from a power position. There is the power position and there is the high pull, and there is the power clean from a power position. These are tremendous exercises. I have read a lot of research recently which says that you are going to get the most benefit out of the

clean high pull. Let us look at that again. They drop down into the power position and they just pull. You can see the triple extension and you can even jump off the floor a little bit. Now, the reason why they suggest you might be able to do the high pull better than the power clean is with a power clean, you still must catch in here, and for some athletes, they may not be able to pull as much weight if they also have to do the catch. You can probably get more weight and more production if you just do the high pull more than the power clean itself, but once again, just a great exercise in here.

We are talking about a progression. What we are doing is we did the clean, we drop down from the power position, we go more to the knee position. They can do the knee position, you can go all the way to the floor. If we watch this progression in here, she lifts up, there is the clean from the knee in there.

If you can do that pretty well, now, you can do a clean from the floor. There is your power clean from the floor. You can go from a power clean into your front squat. That is how you can develop. If you want to teach athletes do the full clean, like we saw in the earlier slide, that would be the way to do it. Once again, now you are going from the knee position, then you drop down to the floor. Some people, you can almost use this as a great warm-up. If you want to develop some mobility in here, start from here, and you drop down. Go a little bit more hip mobility, dropping from the floor. To get a little more stretch, now, you do your power clean and now onto your front squat. This is an excellent progression you can use for athletes.

As I go back in the video, I want to show you the difference between the push press and the push jerk, because they are very similar. The first two repetitions will be the push press. You can see, he is jumping off the ground in here. Here is the push jerk. They are similar, but what is the difference? What are you looking at? If we go through the push press, what you are going to see is you are going to see just a complete extension, really pushing up and driving up. A wonderful exercise. You see him drive up, pushing off the ground, and driving all the way up.

The difference in the push jerk is you are going to push up but you are going to dive. The athlete dives under the bar, so it is more of an eccentric catch in the athletic position. It is more of an eccentric catch, so the bar, instead of just driving up and holding it, you are driving, but getting under and catching. Let me pull that video back. Now, you can see, he is catching that, and he is in the athletic position, catching in there. Great for strengthening the shoulders and stabilizing in here. This is an excellent exercise.

What would I choose for my athletes? Generally, I am probably going to choose more of the push press, especially for my athletes who do not have a lot of experience lifting. I think it is an easier lift for them to do and still develop power. The whole concept is developing power from the ground up.

Let us talk about the deadlift, a great exercise, engages a lot of muscles in the body. In a deadlift, you lift the weight from the ground to thigh level, primarily your leg and hip muscles, but you are using all the muscles. This is a great core exercise. When we talk about strengthening the core, as long as the muscles are firing, they do not have an injury, you are not going to strengthen the core much better than by lifting heavy weight, whether it is a deadlift or just the core engagement you get from doing a squat.

Here, we are going to do a deadlift. From there, you are going to see, the whole idea is getting that hip extension in here and down. The back is staying straight. Here's that straight back, so we are not rounding at all. It is not considered as a technical lift as, let us say, a clean or clean and jerk, but it is still a wonderful exercise. I think when we talk about risk benefit, I think the benefit is a lot greater. You are not risking, as long as they are keeping their position, not lifting too much. I love the deadlift. I am 63 right now, and my motto is deadlift till I die. Just lifting the heavy strength, I think, makes a just a huge difference.

This is a modification. This is what we call a hex bar or a trap bar. Because of these grips, you are raising in a way you grip 8 inches higher the way you grip the bar from the floor. What this allows you to do is if you do not have as a greater mobility, this works very well. We use this with a lot of our high school baseball players. The reason why is they do not have the mobility, they might be a little bit taller, especially pitchers, but the amount of strength you can develop, we have had some pictures, who, their weight training in the offseason has been almost primarily just doing hex bar deadlift, and we have seen an increase in their fastball, for example, 3 to 5 mph. We had one pitcher who was drafted by Major League Baseball, and that difference from his sophomore to junior year, going from 92 to 95 mph, made a big difference in his signing bonus. This is a wonderful modification that you can use.

This is an interesting concept because you will hear people talk about, "proper posture. Do not round the back in here." I think the key in here is not so much, because a lot of your athletes, one of the things you will see is because he does not have good hip mobility, he cannot drop down. look how far his shoulders are in front of his arms. Your shoulders, when you are lifting, should be in line with the arms. This should be straight down in here. The shoulder should be here and arms straight down over the knees. This is because he is leaning too far forward because he does not have the mobility he needs. This is someone who would really benefit from the hexagonal bar, the hex bar lift, if they want to lift heavy weights. The key here is he is not going to hurt himself as long as he does not round the back during the movement. If he can stabilize in here and make this stable movements so he is still just getting hip extension, he is going to be okay. This is something we looked at. If you look at the Strongman competition and they are lifting this boulder, some people, "this is going to be terrible for their back. Look how rounded the back is." No, it is really not going to be terrible as long as you are still getting the hip extension and you are locking this in. You are not letting that spine move it. That spine is locked in, they should be safe.

The squat, fundamental human movement pattern that involves nearly every muscle in the body, very important for mobility, for everyday life, activities of daily living. It is a fundamental movement that we need to have.

I have already shown you the front squat. What I want to show you is some of the progressions you can use and the different squats that could be used, because some people will have trouble. Remember, you put a bar in your back, you are going to get a compressive force, something you must consider. The first thing we will look at is assisted squats, where you can use an elastic band or a trainer. You can drop down into the squat and still maintain good motion.

Looking at body weight squats, one of the things you will notice is you see how the knees are coming past the toes? There is no problem with that. The whole concept of knees do not let the knees go past the toes, as far as I can tell, I heard this at a strength conditioning conference, it all comes from one paper that was published in the 70s that seems to have caught like wildfire, so that became the macho. "do not let the knees go past the toes." I will tell you. In fact, you cannot lift heavy without the knees going past the toes. It is almost a requirement. The other thing you will see is she drops down. You see that rounded back? Sometimes, they will call this the butt wink. In an unloaded position, this is not a problem. If someone wants to round that back in a full squat relaxed, look at babies. They are always in that position.

Whenever we talk about is something a good position, we must talk in context. Are we talking about a loaded position or an unloaded position? This is just body weight. This is unloaded position, so if she drops all the way down, that is not an issue. If she were to have a bar on her back and she got in this position, that would be an issue. Right about here, she is keeping a straight back. Make sure you go down to around 100 degrees, maybe the 90 degrees, but not past that, because when she goes past 90, she rounds the back in here so she may not need the hip mobility she needs. What is also interesting is she

might not round her back if she had a bar in her back. Some people will squat differently with a lower on the back because if you have a lower on your back, your center of gravity changes. Your center of gravity would shift forward, and you might end up standing a little bit straighter.

This is one of my students, a former football player. He had a knee issue so he does a different form of assisted squats, and he uses the box there. He is going to drop down slowly but explode up. He is using the box at this point. This is that eccentric component, isometric, and pop right there. You can use rings, you can use elastic bands, you can use a TRX trainer. These are all excellent supplemental tools.

We go to what we call a landmine squat. Someone who wants to start to lift weight, but they might have trouble with compressing the back or may have trouble maintaining that load, you can do a landmine squat. This is just an attachment. You can see, now, as she drops down, you can see she keeping a pretty good position. She can drive straight up and she can start increasing her weight. This would be a landmine squat.

We can go to goblet squats. She is not compressing the spine. She still has a little bit, so I might want to stop a little bit higher than going all the way down because of that start of rounding of the back at the very bottom of the squat.

I have already showed you the back but let us look at the front squat. With the front squat, you need a little more mobility because you are really resting it right on the clavicles, almost, in there. You need a little more elbow flexibility to do the front squat, but once again, just a wonderful exercise. He is practicing the hold that the bottom. Let us look at that again. If you can hold in there, this is a wonderful exercise. Once you drop down to 90, you are really potentiating what is going on in the glute muscles because you are getting that stretch in the glute. It has got to maintain and then it is got to explode out of that. This is just a great exercise. That is a whole progression of squats that you can use.

Squats. Compared to the deadlift, the squat is more of a knee-dominant pattern. The deadlift and hip-based exercises place more emphasis on the posterior chain development. They both will give an effect for the knee-dominant, the knee pattern, and the posterior chain pattern. I do not want you to think that you are not getting any of these muscles involved; you are. It is just that relatively speaking, the deadlift is more of a hip hinge, whereas you are going to get more extension in the squat. If you are having trouble with compression of the squat because it applies a compressive force, that is when you may want to switch your athletes to more of kettlebell swings.

The reason I say that is a kettlebell swing, you can still develop some good power, but it will be more of a shearing force on the lumbar spine as opposed to a compressive force, whereas the squat will be more of a compressive force with some shearing. You may find some of your athletes just cannot squat, but they could develop some excellent power if they did kettlebell swings.

The bench press. If you are a power lift, you must bench press. We do not use the bench press as much with a lot of our athletes. We still use it with our football players because when they press up, for a lot of our linemen, it is the ability to extend and push off that becomes very important. I would have to tell you for the most part, although a lot of athletes like doing it, the bench press is not as vital to a lifting program as the other exercises that we are dealing with L squat, deadlift, clean and jerk, snatch.

Some of the other training concepts we can look at is we look at combination training where you combine strength and power training. Traditionally, combination training, often referred to adding aerobic training for anaerobic athletes or cross training. The first time I saw the term "cross training" was back, I think, in the late 70s, early 80s, with Sebastian Coe, from the United Kingdom, a great 800, 1500-meter runner. His father had him do circuit training for strength, and they felt that that was what gave him the edge, because distance runners were not doing any strength training at that time. That is

where I first saw cross training. When they talk about cross training, they usually talk about much heavier weights, much heavier loads.

There are different concepts and there are different ways of doing it. Complex training, this is where you do several sets of heavy strain training repetitions and follow it by lighter power movements, or contrast training, where you alternate the strength exercise with the power movements.

Here is what that would look like. This is complex training where you would do your back squats, you would warm up a little bit, and now, you are getting to 85% of your one rep max, heavy loads for three reps, so you are really in that strength power continuum, rest of 180 seconds, making sure you get your rest, but as soon as you do, you do tuck jumps, which is body weight. You are trying to explode, trying to jump up as high as you can for five reps and then 30 seconds, and then five more reps and 30 seconds. This would be one example of complex training.

The thing I do not like about this is five repetitions, if I am really trying to develop power, I am just going to do maybe three repetitions, and I would probably give myself more rest because now, we are really dumping into the metabolic pathways in there. It is still an excellent program, but you are taking a little bit of the benefit you get from power training away with the decreased amount of time. Once again, an excellent workout. This is, if you want to almost potentiate, the ability to explode your jump, works very well.

Instead of complex training, you can also do contrast training. We are doing the back squat, so now, once again, we work up to 85% for three reps and then you do 60 seconds, but you do not rest as much and you go into, maybe, a split squat jump. Once again, I think when you are doing complex and contrast training, you are really working more in this speed strength continuum as opposed to the pure power range, but for a lot of our athletes, this would work very well. If you are talking about soccer players, if you are talking about basketball players, I think this is an excellent way of working, especially if they do not have a lot of experience lifting. This is an excellent way of combining your strength training with power training. One of the keys to this is making sure that whatever you use in terms of your power jumps is similar to the motion you were using in your strength training.

The training concept is your increased excitability of the central nervous system due to post activation potentiation. This is the phenomena we see. We are going to increase the variety of training. If you are going to do this, one is the athletes must work at high intensities. The exercises should be biomechanically similar, and your volume will be low. Once again, it is just a great way of doing some of this training.

If I am doing exercise order within a session, generally, I want to go for power first, maybe a power clean or push press. If you are dealing with Olympic lifters, they are going to be doing whatever their lift is for the day. They may be focusing on the clean and jerk or the snatch. This is where I am dealing with maybe more of just my regular team sport athletes. I will go to the strength, either squat or deadlift, then I will do my supplemental lifts, hamstring curls. Nordic leg curls or Russian leg curls, depending on which part of the world you are in, basically, you are doing eccentric hamstring curls in there. Do I want to work more on my hip flexors in there? Do I have to do maybe some strength, upper body strength, shoulder, rotator cuff-type strength? Generally, within a workout, I have seen some workouts where they are using 12, 14 different exercises, but I want to keep my workouts within a 45 to 60-minute session, if possible.

Just think, if I am doing power, or doing the power clean, do my warm up and my power clean, and I want to do, five sets. If I am doing five sets of two or three repetitions, the actual lifting will only take about 10, 12 seconds, then I am resting three to five minutes. Let us go with the three-minute rest. Basically, every set you do is going to take about three minutes. If I am doing five sets, that is 15 minutes

in there. Then, I am going to my strength. Let us say I want to do five sets of squat or dead, whatever you want to do.

I am looking same thing, same concept, where I am looking at maybe three minutes per set with rest, maybe it goes a little bit longer. The 10 sets, this, already, I do my power and strength, is going to be maybe 30 minutes of the session right in there, and then I am doing my supplementals. Let us say you do supplementals and let us say I am doing my hamstring curls and I am going to do maybe three sets of eight repetitions. Eight repetitions, each repetition takes approximately four to six seconds, that is average, after five. That is going to be about 40 seconds of lifting and maybe 90 seconds, so about 130. We are looking about two minutes per set. If I am doing, let us say, four sets of this at two minutes, that is going to be eight minutes. I am at 38 minutes. If I throw in, maybe, two or three more exercises, that is going to give me one hour.

You can see, if you really want to do an exercise session where you are doing some power, you are doing some strength and supplemental work, you are not doing 12 different exercises. You can choose maybe a power exercise, a strength exercise, and then three to four supplemental exercises, and that is going to give you a high-quality workout. If you are going more than 60 minutes, most people start to lose their focus at 45 to 50 minutes. Athletes can go longer, so maybe you can get them into that 60 to 80-minute range, but you are definitely not going to be doing an exercise session where you are going to be throwing 12 different exercises at them. You are not going to get as much benefit from that as to keeping it almost compact. Keep it simple. You can vary it from week to week when we talk about periodization.

Perfect segue, periodization. Periodization, it is a strategy designed to prevent overtraining and optimize peak performance. Training is often organized into cycles: macro, meso, and microcycles. This is arbitrary. What I mean by that is it depends on the athlete. For example, if you are looking at an Olympic athlete who is training for one Olympics to the next, that four-year period would be their macrocycle, then they may divide their macrocycle up into the mesocycles, which might be one-year cycles, where they are going for the World Championships every year.

That one-year cycle, you divide that up into your microcycles, which could be three-month periods where you are accentuating certain things. For example, if we look at a 12-month period of microcycle for an athlete, maybe they do one to two months of hypertrophy training volume, then one to two months of strength, and one to two months of power, and they repeat that three or four times, and that would make up the entire mesocycle.

For a soccer player, what are they peaking for? That is going to be much tougher. If you take someone in the EPL, they start in the Fall, but do they really want to peak for the Fall? Yeah, they want to be in their greatest shape as possible, but can they maintain that, then, throughout the season, with all the different matches and contests that they are doing? They might have UEFA games along with their regular season games. What exactly do you want to peak for? Much tougher to do in a seasonal sport like that.

A lot of what we talk about is the General Adaptation Syndrome. This is Hans Selye, who was a Hungarian-Canadian endocrinologist, and these were rats studies the did. He subject the rats to drugs and different stimuli, physical activity, and he would notice first that you have the alarm reaction and then they develop resistance to the alarm, but if you go too far, then they end up exhaustion, and possibly, death. Well, this was adapted for strength training by Mike Stone in 1982. The Theoretical Model of Strength Training is that you start putting resistance load on the athlete, the body, and that is the alarm, then if they adapt and go quickly, that is the resistance. The body develops a resistance, and this is where they start getting stronger, but you can get into overtraining. If you go in too much into

overtraining, that is where injuries will start occurring, but you can also have almost a mental injury or fatigue when we talk about overtraining. Overtraining can be physical, it can be mental, and we talked about overtraining, it can be local and it can be central nervous system fatigue also.

When we look at periodization, the whole concept in here, this is, I believe, a Klavora chart, you have your preparatory period for the athlete. This is where they develop, do a lot of volume, they get prepared for the higher intensity activity. You can see, intensity is lower. Their technique is lower, they are taking it easy, but they are doing a lot more volume. The transition period, this is where they want to start getting stronger. Your volume decreases, your intensity increases, you start to increase your training technique, then you have your competition period. You are hoping that this is where you have your greatest strength in here. Are you peaking, here is your technique, at the most important time?

I often talk about, for example, in the United States, the college players let you know, some of the soccer players, what are they peaking for. Well, for incoming freshmen who are trying to make the team, they are trying to peak for tryouts so they can put their best foot forward to make the team, whereas if you are a returning player, you are really peaking for the first game of the season. You may not be coming into your greatest shape at the beginning of training camp; you are trying to peak for the first game.

Here is Klavora's study. Your biological state, we talk about supercompensation, but this is kind of a vague concept because the only time we have actually tested and seen actual changes in supercompensation occurs with glycogen. We really have not seen it with the other system, so this is all theoretical in here. Here is where you start, and what you will do is if you do not work out hard enough, you do not get much change in here. This is that nice spot where you work out, you have fatigue, but then the body starts adapting, and then you get what they call the supercompensation. If you train too hard, you enter fatigue and you never really recover. You may not even get back to your baseline performance.

This supercompensation that we are talking about may not be supercompensation at all. What it might be is the concept of that when you come in here and you start tapering, it is just the fatigue goes away. When we look at the different paradigms, the paradigm we are looking at is the fitness fatigue paradigm, where when you are working out, you are getting in better fitness, but you are also increasing your fatigue, and this occurs concurrently. What will happen is as you work out harder, you adapt more and the fatigue starts to dissipate, so your fitness becomes more apparent even though it may have been not much different than here. The after effect in fitness and fatigue are exercise-specific. If you are training one exercise, let us say you are training the squat, that does not mean you are going to get that same benefit in the clean and jerk or in the snatch.

The key to periodization is your taper in reducing training to enhance performance. You can have a reduction in volume intensity and/or frequency, fatigue dissipates, and that is where your fitness becomes really apparent. What is interesting is when we talk about tapering, we do not know how much you should taper. For example, I have football players, American football players, high schools, who may have a Friday night game, but they will lift intense on Friday morning.

When I say intense, I mean 90% of the max lift, but maybe one to two reps with increase so their volume is very low, but they try and get that stimulus for the game and they seem to have some effect. If you look at weightlifters who are competing on a Saturday, for example, some weightlifters will tell you they do not want to lift one or two days before the competition. Some lifters will tell you, "No, I am going to continue to lift at an intense stimulus, but very low volume, very high rest periods," and they feel that is what prepares them best to peak on their competition. It is very athlete-specific.

There are differences. Linear periodization, which is designed for peak performance at a specific time, for example, your Olympic athletes, and undulating periodization, designed to maintain high

performance for longer periods of time. This would be your seasonal athletes, your soccer players who have to compete for the entire season.

Here is an example of a 12-month football training program. You can see, I am going to go to September because this is when the college or high school football starts in the United States. You can see in season. It is all about maintaining power and maximal strength throughout the season, and you will find a lot of athletes, once the season starts, do not want to lift this much. They will end up suffering from a decrease in strength and power as the season continues. It is very important, especially with professional sports. You will see them training, which can be tough. For example, a professional football team in the United States, if they have a game on Sunday, they are beat up on Monday. Monday is just a recovery day. Tuesday might be a strength day, where they will do some strength work, but they will not go too intense because they are still recovering. In fact, a lot of times Tuesday, in the National Football League, Tuesday mornings is what they call Community Day where they do community outreach, go to local hospitals, local schools, and then they have practice in the afternoon. Wednesday or Thursday will become their main lifting day.

A lot of the football players will lift heavy on Wednesday and maybe on Friday. This is where they have Saturday to recover, and they play on Sunday. You can see, especially with the scheduling, what happens if they have a Monday night game or a Thursday night game, which may happen two or three times in the season? It can really throw up their lifting. This is the problem that the athletes deal with.

Getting back into our periodization in season, January is transition rest. Generally, when we talk about rest, we talk about active rest, where they are still doing some sort of activity, maybe they are just not lifting. They go into February, their strength training is more of their functional strength training in here, and then they are going to do very little speed and agility training. As you go further into the offseason in here, now, we talked about our hypertrophy training, now, it is volume, but it is still low speed agility training. As you start getting into more strength training, maximal strength training, it is intense, but lower volume, so you start going into more speed and agility training, more technique, then you get into your power training, and then you do even more speed and agility training technique. Then you repeat the whole thing, where you go hypertrophy, more strength, and then into power, and once again, your speed and agility training.

You can see, speed and agility training are as high as when we combine that with power training. You can see how we will do this. This is a linear periodization, a year of linear periodization. This is the entire macrocycle versus an Olympic lifter, whose macrocycle might be four years.

The concept of undulating periodization is where, instead of doing periodization by month, you do periodization during the week. If we look at a weekly undulating period in here, Day 1, Day 2, Day 3, Day 4, and so forth, maybe on that first day, let us say we are talking about a Monday, they may do maximal strength in here, where they are doing lower body and they are doing a lot of pushing. On Day 2, they are doing maximal strength, but now, they are doing more upper body and pushing. Day 3, they will drop down in intensity and do more hypertrophy, so more volume, but lower intensity, then they will come into their power workout, once again, high intensity but a lower volume, and then maybe Day 5, they will go into a maximum strength again and they will focus on lower body but more of a pulling-type motion, and then they will do some strength endurance. This is just one example of undulating periodization.

I would say something that is more active in the athletes I train. For example, let us talk about the high school level, where maybe they are training weights Monday, Wednesday, Friday. Monday, maybe they had the weekend to rest, so Monday may be their power day. Wednesday would be their volume day,

and then maybe Friday would be a strength day because they have a game on Saturday or game on Friday night. There are different ways of varying it. Once again, this will be more athlete-specific.

Very important if you read this. The Basics of Training for Muscle Size and Strength: A Brief Review on the Theory of Periodization. Periodization, as presented in the available literature, does not appear necessary for achieving optimal increases in muscle size and strength within a training program. In the context of sports performance, no evidence exists outside of anecdotal reports that longer-term periodization strategies and variations used actually support enhanced sports performance over merely repeated deliberate practice of that specific task.

Here, I am talking about periodization. It is a very important concept in strengthening and conditioning, but it is theoretical in nature, and that is why I say how important it is to work with your athletes in terms of how they feel and what they can do. I would tell you that periodization, anecdotally, is very important because they need these rest periods. They need the recovery, which is what helps them gain their strength. Just on a physiological basis, if you are not doing some sort of periodization in terms of lifting and recovery, you are not going to get the effects, you are not going to get the strength adaptations that you are looking for.

Here are some of the organizations that I like. FICS and ACASC, the American Chiropractic Association Sports Council are organization that I like to follow. For a lot of information, the American College of Sports Medicine, just a wonderful group, and this is good because you can follow epidemiological studies, you can follow studies on a cellular level.

For my national organization, National Strength Conditioning Association, I feel, is a great organization which puts out great information. I also follow United Kingdom Strength and Conditioning Association, excellent organization. www.Strengthandconditioning.org is the Australian organization.

Some of the research that comes out of the UK and Australia is just wonderful. www.Allthingsgym.com is a great site if you are interested in weightlifting, if you want to see a great technique, see great lifts, this is just weightlifting. You are going to see the clean and jerk, see the snatch, and it follows all the different international lifters. I just think that is a great source of information,

If you want to reach me, email: aklein@nwhealth.edu I am the Director of Northwestern Health Science in the Human Performance Center.

I am not a big social media person, but I will sometimes post on @andyklein33 on Instagram if I find an interesting research concept, or sometimes.

[END Session 1 of Exercise Physiology]