

Science of Muscle Growth, Increasing Strength & Muscular Recovery | Huberman Lab Podcast #22

In this episode I describe how our brain and nervous system control muscle tissue and how to leverage that for muscle maintenance, growth (hypertrophy) and recovery. I explain muscle metabolism and muscle fiber recruitment. I detail protocols for increasing muscular growth and for neuro-muscular recovery. I explain the effects of deliberate cold, anti-inflammatory agents, and anti-histamines on training progress. I describe science-supported protocols using certain weight load ranges, total sets per week, training intensity, frequency, and in-between set activities if one's goal is to increase muscle growth, strength or endurance. I review three foundational compounds and nutrients and three optimization compounds and nutrients that have been shown to improve neuro-muscular performance. Finally, I explain how to leverage exercise and weight training to enhance cognitive function.

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- [Andrew Huberman] Welcome to the Huberman Lab Podcast where we discuss science and science-based tools for everyday life. - I'm Andrew Huberman, and I'm a

Professor of Neurobiology and Ophthalmology at Stanford School of Medicine. This podcast is separate from my teaching and research roles at Stanford. It is however, part of my desire and effort to bring zero cost to consumer information about science and science-related tools to the general public. In keeping with that theme, I'd like to thank the sponsors of today's podcast. Our first sponsor is InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better understand your body and reach your health goals. I've long been a fan of getting blood work done for the simple reason that many of the things that impact our immediate and long-term health can only be analyzed from a quality blood test. And now with the advent of modern DNA tests, we can also get insight into things like metabolic factors that tell us whether or not we metabolize caffeine well or certain proteins well, what our fat metabolism genes are like. Things of that sort can only be analyzed from quality blood and DNA tests. In addition, many of the factors that impact our hormones, our metabolism our brain health, those come back in a blood and DNA test and there are many blood and DNA tests out there, but with InsideTracker, they give you a lot of clear insight into what those markers mean and how to adjust them. They have this terrific platform that doesn't just give you the numbers back and tell you if you're higher or low in some factor, but rather it tells you what your levels are of all those factors and gives you very simple and clear directives of changes you might make in your diet, changes that you might make in your exercise regimen, or sleep, et cetera in order to get those markers where they ought to be and where you would like them to be in order to optimize yourself. So they make everything very easy, start to finish. They can even come to your home to take the blood and DNA tests if you like. If you'd like to try InsideTracker you can go to insidetracker.com/huberman. And if you do that, you'll get 25% off any of InsideTracker's plans. Use the code Huberman at checkout. Today's podcast is also brought to us by Belcampo Meat Company. Belcampo is a regenerative farm in Northern California that raises organic grass fed and finished certified humane meats. While I don't eat a lot of meat, when I do I insist that that meat be a very high quality. How the animals were cared for is extremely important to me and the life that the animal had and what it consumed is very important to me. So the way that I eat I've discussed on this podcast before but very briefly, I basically fast until about noon, then I eat a piece of beef or chicken with lunch and a salad. So that's basically my lunch. That's what optimizes my levels of alertness for work throughout the day. Then in the evening I shift over to eating primarily carbohydrates. That's what allows me to sleep

very well. So I'm not eating huge volumes of meat but am eating meat every day. Conventionally raised animals are confined to feed lots and need to diet of inflammatory grains which is bad for them and it's bad for us when we eat their meat. Belcampo animals graze on open pastures and seasonal grasses resulting in meat that is higher in nutrients and healthy fats. And I've talked before about the importance of omega-3 fatty acids for both brain and body health and Belcampo meats are high in omega-3 fatty acids. The way Belcampo raises its animals isn't just better for your health, it also has a positive impact on the environment. It's what's called climate positive and carbon negative which means good for the planet and good for us. My favorite meats from Belcampo are the rib eye and the flank steaks. That's typically what I eat. I think I probably eat about three or four of those across the week and then I'll eat chicken on some other days. They're really delicious, and as I mentioned, they're very good for us. You can order Belcampo sustainably raised meats to be delivered straight to your door using my code Huberman at belcampo.com/huberman. If you do that, you'll get 20% off first time order. That's belcampo.com/huberman for 20% off your first order. Today's episode is also brought to us by Headspace. Headspace is a meditation app backed by 25 published studies and has over 600,000 five star reviews. So I've been meditating on and off since I was about 15, 16 years old, mostly off at first. What I found is that I'll sometimes start a meditation practice but it's very hard to stay with. And then a few years ago I discovered Headspace and I started meditating more regularly. In fact, very recently because I've had an exorbitant amount of work on my plate and I've been getting less sleep than I would like in order to complete that work, I've brought back a regular meditation practice twice a day not just my usual once a day. Headspace makes it really easy. They have so many meditations on there and they guide you into the meditation and out of the meditation in a way that just makes it very simple and makes maintaining the practice really straightforward. Right now if you want to try Headspace you can go to [headspace.com/special offer](https://headspace.com/special-offer). And if you do that, you'll get a free one month trial. So that's totally free with their full library of meditations for every situation. So there's no meditations that you can't get access to with this offer. You can get access to everything they've got. You just go to [headspace.com/special offer](https://headspace.com/special-offer). You get a free one month trial and hopefully you'll decide to stay with it. I've found that staying with meditation has been immensely beneficial for all aspects of my life. Today's episode of the Huberman Lab Podcast is our fourth and final episode in this month which is all about skills and athletic performance. Now, in a previous episode, we talked about

science-based in particular neuroscience-based tools for accelerating fat loss. Previous to that, we talked about ways to improve skill learning, motor movements which also included things like music and piano playing not just athletic performance. And we've also been exploring other aspects of physical performance throughout the entire month. Today I want to talk about something that is vitally important for not just athletic performance, but for your entire life and indeed for your longevity, and that's muscle. Now, many of you, when you hear the word muscle think muscle growth and building big muscles. And while we will touch on muscle hypertrophy muscle growth today, and science-based protocols to enhance hypertrophy, we will mainly be talking about muscle as it relates to the nervous system. And I can't emphasize this enough the whole reason why you have a brain is so that you can move. And one of the things that's exquisite and fantastic about the human brain, is that it can direct all sorts of different kinds of movement, different speeds of movement, movement of different durations. We can train our musculature to lift heavier and heavier objects or we can train our musculature to take us further and further so-called endurance. We can also build smoothness of movement, excuse me, smoothness of movement as well as speed of movement, suppleness of movement. All of that is governed by the relationship between the nervous system, neurons and their connections to muscle. So when you hear the science of muscle and muscle hypertrophy, you might think, oh, well I'm not interested in building muscle but muscle does many critical things. It's important for movement. It's important for metabolism. The more muscle you have and not just muscle size but the quality of muscle, that's a real thing, the higher your metabolism is, and indeed the healthier you are. It turns out that jumping ability and ability to stand up quickly and to get up off the floor quickly is one of the most predictive markers of aging and biological aging and no surprise that is governed by the brain to muscle connection. In addition, muscle and musculature is vital for posture and we don't talk about posture enough. We all have been told we need to sit up straight or stand up straight, but posture is vitally important for how the rest of our body works. It's vital to how we breathe. It's actually even vital to how alert or sleepy we are. So we're going to talk about the musculature for posture. We also are going to talk about muscle as it relates to aesthetic things. Now, these are all linked. Muscle for metabolism, movement, posture and aesthetics of course are linked, right? As our posture changes, our aesthetic changes. As our posture and aesthetic changes, how we move changes. And as we improve muscle quality whether or not that's increasing muscle size or not, that changes the way that our entire system not just

our nervous system and our muscular system but our immune system and the other organs of the body work. So today, as always we're going to talk a little bit of mechanism. I'm going to explain how neurons control muscle and then we're going to look at muscle metabolism, how muscle uses energy. I promise to make all of this very simple. I'm actually going to keep it very brief probably about 10 minutes total. And by the end of that 10 minutes, you will understand a lot about the neuromuscular connection, how your brain and nervous system control your muscle and how those muscles work. Then we are going to talk about how muscles use energy and can change how they use energy for sake of getting stronger, if you like for also increasing the size so-called hypertrophy of muscle and for improving endurance as well as for improving posture and how you move generally. We will touch on some nutritional themes and how that relates to muscle in particular a specific amino acid that if it's available in your bloodstream frequently enough, and at sufficient levels, can help you build and improve the quality of muscle. And we'll talk about specific exercise regimes as well as of course, supplementation and things that can enhance neuromuscular performance overall. We are also going to talk about recovery. Recovery as everybody knows, is when things improve. That's when neurons get better at controlling muscle, that's when muscle grows, that's when muscle gets more flexible. None of that actually happens during training. It happens after training and there is a lot of confusion about how to optimize recovery and how to measure whether or not you are recovered and ready to come back in for another neuromuscular training session. So we'll talk about that as well. Today is going to have a lot of protocols and you're going to come away with a lot of understanding about how you move, how you work

00:10:58 Protocol For Fat Loss: (Zero-Cost) PDF Available At: thecoldplunge.com

in these incredible organs that we call the nervous system and the musculature, the so-called neuromuscular system. Before we dive into today's topic, I want to just take about three minutes and cover some essential summary of the previous episode. In the previous episode, we talked about fat loss. Talked about shiver induced fat loss. We talked about neat non-exercise activity thermogenesis for increasing caloric burn and fat oxidation. And we talked about how to use cold specifically to enhance fat loss. I described a protocol involving getting into cold of some sort, whether or not it's ice bath, cold shower, some form of cold could even be a river or an ocean if you have access to

that and inducing shiver and then getting out, not crossing your arms or huddling but allowing that cold to evaporate off you and continuing to shiver and then getting back into the colder environment of water or stream or shower, et cetera. All of that is described in a beautifully illustrated protocol that I didn't illustrate. That's why it's beautifully illustrated at the coldplunge.com. They've made that protocol for you and they've made it available free of charge for you. So there's no obligation there of any kind financially. You can go to the coldplunge.com. There's a little tab that says protocols and you can download that protocol, someone there I don't know who exactly illustrated it, and you can come away with a PDF of what I described in the previous episode. So I just want to make sure that you are aware of that resource. The other announcement I'd like to make is that many of you have asked how you can help support the podcast. And there's a very straightforward zero cost way to do that. And that's to subscribe to our YouTube channel. So if you go to YouTube, if you're not already there watching this now hits the Subscribe button that helps us tremendously

00:12:45 Muscle Is A Slave To the Nervous System

to get the word out more broadly about the podcast. And we thank you for your support. Most people, when they hear the word muscle they just think about strength. But of course muscles are involved in everything that we do. They are involved in speaking, they're involved in sitting and standing up, they're involved in lifting objects, including ourselves. They are absolutely essential for maintaining how we breathe. They're absolutely essential for ambulation, for moving, and for skills of any kind. So when we think about muscle, we don't just want to think about muscle the meat that is muscle, but what controls that muscle. And no surprise what controls muscle is the nervous system. The nervous system does that through three main nodes of control areas of control. And I've talked about these before on a previous podcast. So I will keep this very brief. Basically, we have upper motor neurons in our motor cortex. So those are in our skull and those are involved in deliberate movement. So if I decide that I'm going to pick my pen up and put it down, which is what I'm doing right now, my upper motor neurons were involved in generating that movement. Those upper motor neurons send signals down to my spinal cord where there are two categories of neurons. One are the lower motor neurons and those lower motor neurons send little wires that we call axons out to our muscles and cause those muscles to contract. They do that by dumping chemicals onto

the muscle. In fact, the chemical is acetylcholine. I've talked before about acetylcholine in the brain which is vitally important for focus and actually can gain neuroplasticity, the brain's ability to change in response to experience. But in the neuromuscular system, acetylcholine released from motor neurons is the way the only way that muscles can contract. Now, there's another category of neurons in the spinal cord called central pattern generators or CPGs. And those are involved in rhythmic movements. Anytime we're walking or doing something where we don't have to think about it to do it deliberately, it's just happening reflexively that central pattern generators and motor neurons. Anytime we're doing something deliberately, the top-down control as we call it, from the upper motor neurons comes in and takes control of that system. So it's really simple. You've only got three ingredients. You've got the upper motor neurons, the lower motor neurons and for rhythmic movements that are reflexive, you've also got the central pattern generators. So it's a terrifically simple system at that level, but what we're going to focus on today is how that system can control muscle in ways that make that system better. Now, when I say better, I want to be very specific. If your goal is to build larger muscles, there's a way to use your nervous system to trigger hypertrophy to increase the size of those muscles. And it is indeed controlled by the nervous system. So you can forget the idea that the muscles have memory or that muscles grow in response to something that's just happening within the muscle, it's the nerve to muscle connection that actually creates hypertrophy. I'll talk exactly about how to optimize that process. In addition, if you want to improve endurance or improve flexibility or suppleness or explosiveness, that is all accomplished by the way that the nervous system engages muscles specifically. And so what that means is we have to ask ourselves are we going to take control of the upper motor neurons, the central pattern generators, or the lower motor neurons or all three in order to get to some end point

00:16:22 Why We Have A Brain

of how the nervous system controls muscle. So neurophysiology 101. I'll give you one piece of history because it's important to know. Sherrington, who won the Nobel prize called movement, the final common path. Why did he say that? Well, the whole reason for having a nervous system the whole reason for having a brain is so that we can control our movements in very dedicated ways. That is one of the reasons, perhaps the predominant reason why the human brain is so large. You might think, oh it's so large for

thinking and for creativity. Ah, no when you look at the amount of real estate in the brain that's devoted to different aspects of life, it's mainly vision, our ability to see and movement, our ability to engage in lots of different kinds of movements. Slow movements, fast movements, explosive, et cetera. Other animals don't have that ability because they don't have the mental real estate. They don't have the neural real estate in their brain. They have neuromuscular junctions. They have central pattern generators what they don't have are these incredible upper motor neurons that can direct activity the muscles in very specific ways. So we can all feel blessed that we have this system.

00:17:38 Flexors, Extensors, & Mutual Inhibition

And today I'm going to teach you how to use that system toward particular end points. So if we decide that we are going to direct our muscles in some particular movement of any kind. Whether or not it's a weightlifting exercise, or whether it's a yoga movement or simply picking up and putting down a pen, we are engaging flexors and extensors and our body is covered with flexors and extensors all over. So for instance, our bicep is a flexor and our tricep is an extensor. Those are what are called antagonistic muscles. They move the limbs in opposite directions. So if you bring your wrist closer to your shoulder, that's flexion using your bicep. If you move your wrist further away from your shoulder, that's extension, using your tricep. And without getting into a lot of detail the way that the nerves and brain are wired up to muscle make it such that when a flexor is activated, when the nerve dumps chemical acetylcholine onto the muscle to activate the biceps, the triceps is inhibited. It's prevented from engaging. There are ways to bypass this but that's the typical mode of action. The converse is also true when our tricep is in activated, when we move our wrist away from our shoulder our bicep is inhibited. And we have flexors like our abdominal muscles. And we have extensors in our lower back. Many of you probably know this but some of you probably don't that your spine has flexors to move basically your chin toward your waist. And it has, those are your abdominal muscles among others. And you have extensors that move your chin, basically back like looking up toward the ceiling. And those are your extensors. You have other muscles that are stabilizing muscles and things of that sort but those movements of flexion and extension, and the fact that they are what we call reciprocally innervated or mutual inhibition, you hear different language around this is characteristic of most of our limb movements. So hamstring and quadriceps, the hamstring brings the

ankle closer back towards the glutes. Basically it's lifting your heel up which is almost always done toward the back. Whereas your quadriceps is the extensor opposite to the hamstrings. So you get the idea. So there's flexors and extensors and it's the neurons that control those flexors and extensors that allow us to move in particular ways.

00:20:00 How Muscles Move, Making & Using Muscle Energy: Making ATP

So, now you have heard a neuromuscular physiology in its simplest form, but I do want this to be accessible. I want to get just briefly, just briefly into some of the underlying metabolism of how muscles use and create energy. Because in doing that, we will be in a great position to understand all the tools that follow about how to optimize the neuromuscular system for your particular goals. So in the previous episode about fat loss, we talked about lipolysis. The breakdown of fat into fatty acids so it can be used as fuel. And it ended in a step where we got ATP, which is the bottleneck and final common path for all energy producing functions in the body. There are other ways but basically ATP is the key element there. Now with muscles, they don't function on fats normally what they are going to function on their ability to move and their ability to do things and allow us to move in any way that we want to, is based on a process of glycolysis, the breakdown of things like glycogen and glucose into energy. And it's a very simple process. You don't have to know any chemistry. So if I say the words carbon or hydrogen or something like that, don't freak out. You don't have to understand any chemistry. But basically what happens is you've got this available sugar resource that stored in muscle. And that's glucose. And that glucose has six carbons and six waters, basically. That can be broken down into two sets of three carbons. All right. So basically you take glucose and you break it into these two little batches of carbons that we call pyruvate. So six divided by two is three. So you get three and three pyruvate. And that generates a little bit of ATP of energy but just a little bit. Now, if there's oxygen available, if there's sufficient oxygen there, what can happen is that pyruvate can be brought to the mitochondria and through a whole set of things that you probably don't want to hear about right now like the electron transport chain and citric acid cycle. What happens is it's broken down and you get 28 to 30 ATP, which has a lot of ATP. So the only things you need to know, the only things you need to know about this process is that glucose and glycogen are broken down into pyruvate. You a little bit of energy from that. And when I say energy, I mean the ability to move. It's fuel, literally just gets burned up. But if

there's oxygen available and that's key then within the mitochondria, you can create 28 to 30 ATP which is a lot of ATP. Now, what does this mean? This means that movement of muscle is metabolically expensive and indeed compared to other tissues compared to fat, compared to bone, compared to almost all other tissues, except brain tissue muscle is the most metabolically demanding which is why people who have more muscle relative to adipose tissue to fat, they can eat more and they're more of a furnace. They just kind of burn that up. So even if you didn't understand anything that I just said, what you probably did hear, and that I hope you heard is that if you have oxygen around, you can create energy from this fuel source that we call glycogen and glucose. But what if there isn't oxygen around? And what is that like? Well, you've experienced that. I'm not talking about oxygen in the environment.

00:23:29 The "Burn" Is Not Lactic Acid. Lactate: A Buffer (Prevents Acidity), Fuel, & Hormone

I'm talking about oxygen in the muscle. So if you've ever carried a box while moving, or you're carrying heavy groceries to the car, or you're exercising particularly hard and you felt the burn, well, that burning which most people think is lactic acid is actually a process by which pyruvate, which as I said before normally could be converted into ATP if there's oxygen, well, if there's not enough oxygen 'cause that muscle is working too hard or too long, what ends up happening is that a hydrogen molecule comes in there and you get something called lactate. So believe it or not, humans don't make lactic acid. That's another species, we make lactate. And we hear that lactate is bad. We need to buffer the burn or avoid the burn. That lactic acid and lactate are what prevent us from performing as well as we ought to be able to or going as far as we possibly could in an endurance event. Guess what, that's not true at all. Lactate has three functions, all of which are really interesting and really important. First of all, it's a buffer against acidity. You don't want muscle to get too acidic because it can't function. You don't want any body tissue to get too acidic. So that burn that you feel is acidity in that environment and lactate what most people call lactic acid, but again, we don't make lactic acid. Lactate is there to buffer that to reduce the amount of burn. So, most people have this exactly backwards. So when you feel that burn that is not lactic acid, that is lactate that's present to suppress the burn, to suppress acidity. It's also a fuel. When you feel that burn, lactate is shuttled to those areas of the muscle, and there's an actual fuel burning process

where in the absence of oxygen you can continue to generate muscular contractions. Now, this is informative 'cause it also tells us that that burning that acidity that we feel can inhibit the way that our muscles work but that lactate comes in and allows our muscles to continue to function. So we'll talk a little bit more about what this whole lactate thing and the burn means but it's a really important process. And it's amazing to me that most people understand it in exactly the incorrect way. They think a lactic acid is bad and the burn is bad. No, it reveals a number of really important things are going on with this vital molecule lactate, which can reduce acidity, reduce the burn as well as act as a fuel. Now, here's where it gets really, really cool. And if you don't have enough of an incentive to exercise based on all the information out there about how it'll make you live longer

00:26:11 Feeling the Burn For 10% of Workouts Is Good For Brain, Heart, Liver

and make your heart better, et cetera, here's a reason that regardless of what kind of exercise you do, if it's weight training, or running, or cycling, or swimming that every once in a while, about 10% of the time you should exercise to the point of intensity where you start to feel that so-called burn. The reason for that is that lactate shows up to the site of the burn, so to speak, and it acts as a hormonal signal for other organs of the body in a very positive way. As you may recall, from a very early episode of the Huberman Lab Podcast, I talked about what a hormone is and how it works. We have lots of different kinds of hormones but hormones are chemicals that are released in one location in the body and travel, have effects on lots of other organs of the body. So when I say that lactate acts as a hormonal signal, what I mean is that it's in a position to influence tissues that are outside of the muscle. And basically it can send signals to the heart, to the liver and to the brain, and it can have effects on the heart, the liver and the brain that are very positive. So just to zoom out for a second I promise we won't get any more technical than this.

00:27:30 Leveraging Lactate To Enhance Brain Function

We will get into tools and protocols that are really straightforward but what I'm telling you is that if you feel a burn from a particular exercise or movement, that burn is going to be buffered by this molecule we call lactate. Lactate will then provide additional fuel for

additional work. So this is a good incentive provided you can do it safely to "Work through the burn." That burn acts as a beacon to the lactate which comes in and allows you to do more work. It's not a signal to stop necessarily. I mean, stop if you're doing something unsafe but it's a signal that lactate should come in and allow you to continue to do work. And it can act as a hormonal signal. Lactate can then travel to the heart and to the liver and to the brain and can enhance their function in positive ways, not just in those moments, but in the period of time that follows. So many people are curious about how they can exercise to make their brain better. That's one of the most common questions I get. What I'm telling you is that provided you can do it safely by engaging the so-called burn which is at a different threshold for everybody, your hill run will be different than my hill run to generate the burn, but provided you can do that for about 10% of your workouts or of an individual workout, or activity of any kind, you are generating the activity of this lactate based hormonal signal that can improve the function of neurons. And it does that if you want to know for the aficionados by improving the function of another cell type called the astrocytes which are a glial cell type. Which are very involved in clearance of debris from the brain, they're involved in the formation of synapsis connections between neurons in the brain. So put simply, if you are an exerciser if you're doing movement of any kind, and you're interested in allocating some of that movement toward enhancing brain, heart and liver health, there is a nice set of scientific data that points to the fact

00:29:40 Breathing Properly Through "The Burn"— For Sake of Performance & Brain Function

that getting a lactate shuttled to the muscles by engaging this burning sensation is advantageous for the health of those other tissues. So, as I mentioned that burn is present from lack of oxygen being present. And then the hydrogen comes in and you get this lactate. But this process of lactate acting as a buffer of fuel and a positive hormonal signal for other tissues, occurs only if there's oxygen. So if you feel the burn, you definitely want to focus on your breathing at that point. That would be the time to take deep inhales and try and bring more oxygen into your system. It's definitely not a time to hold your breath. And if ever you've run to the point of feeling the burn and then you were exercised in any way on the treadmill or on the bike or whatever, and felt that burn, and then you held your breath, it feels much more intense. By breathing you bring

lactate to the site and you are able to allow lactate to act more as a buffer, a fuel, and a hormonal signal. And the reason I brought this up today is because as I mentioned so many people are interested in using exercise not just for sake

00:30:47 Neurogenesis (New Neurons) & Exercise: Not Much, In Humans... Which Is Good.

of improving physical health and wellbeing and performance, but also for enhancing their brain. And there are a lot of data out there speaking to the findings that exercise of various kinds can increase neurogenesis, the creation of new neurons. Well, the unfortunate news is that while that's true in mice, there is very little evidence for enhanced neurogenesis from exercise or otherwise in humans. There's a little bit, and there are a few sites within the brain, such as the dentate gyrus of the hippocampus, which may be involved in the formation of new memories, to be clear the dentate gyrus is definitely involved in the formation of new memories, whether or not the new neurons that are added there in humans are involved in new memories. The evidence for that is weak at best, frankly whereas in animals the data are quite strong, but most of the data points to the fact that hormonal signals, things that are transported in the blood during exercise are beneficial for the brain and that those signals are not causing the increase in the number of neurons in the dentate gyrus or otherwise. That it's more about the health of the connections between the neurons growth factors of various kinds things like IGF-1, there's a long list of these things. So if you've heard the exercise increases the number of neurons in your brain, well, that's not true. And that probably is a good thing, frankly because we always hear more neurons, more neurons as if it's a good thing, but the brain doesn't do so well with bringing in entirely new elements. It has a hard time negotiating that and making use of those new elements. We know about this from things like the cochlear implant where deaf people are given a device where they suddenly can hear. Some people really like that, deaf people really like that and can benefit from it. Other deaf people find that it's very intrusive. That is hard to take an existing neural circuit in the brain and incorporate a lot of new information into it. So new neurons, as great as that sounds more neurons, more neurons, it actually might not be the best way for the nervous system to change and modify itself and to promote its own longevity. So when I tell you not such great evidence from new neurons past puberty, that's what the data really show in humans. And I sort of knocked back the data on exercise and

neurogenesis, don't let that depress you. If you have dementia in your family, don't translate that into necessarily that you will develop dementia. Understand the exercise is still beneficial for the brain and other aspects of the nervous system but that it's going to be doing it through these hormonal signals. Things like IGF-1, things like this lactate pathway when you experience the burn from exercise. And again, you don't want to try and get this feeling of a burn throughout the entire episode of exercise, there'll be far too intense and would inhibit your recovery. I don't think it'd be good for performance either.

00:33:39 How To Contract Muscles, Make Them Bigger and/or Stronger: Henneman's Principle

It's only about 10% of your total effort in any one exercise about that's going to give you this positive effect. So now you know how to devote a small portion of your exercise, 10% in order for muscle and lactate to benefit other tissues namely your heart, your liver, and your brain. I'd now like to shift our attention to how to use specific aspects of muscular contraction to improve muscle hypertrophy, muscle growth, as well as improving muscle strength. There are a lot of reasons to want to get stronger. And I should just mention that it's not always the case that getting stronger involves muscles getting bigger. There are ways for muscles to get stronger without getting bigger. However, increasing the size of a muscle almost inevitably increases the strength of that muscle at least to some degree. Reasons why most everyone should want to get their muscles stronger is that muscles are generally getting progressively weaker across the lifespan. So when I say getting stronger, it's not necessarily about being able to move increasing mounts of weight in the gym. Although if that's your goal what I'm about to discuss will be relevant to that, but rather to offset some of the normal decline in strength and posture and the ability to generate a large range of movement safely, that occurs as we age. As I mentioned at the beginning of the episode we just tend to lose function in this neuromuscular system as we get older. And doing things to offset that has been shown again and again, to be beneficial for the neuromuscular system for protection of injury, for enhancing the strength of bones and bone density. So there are a lot of reasons to use resistance exercise that extend far beyond just the desire to increase muscle size because I know many of you are interested in increasing muscle size, but many of you are not. So there's an important principle of muscle physiology called the Henneman size principle. And the Henneman size principle essentially says that we

recruit what are called motor units. Motor units are just the connections between nerve and muscle from in a pattern that staircases from low threshold to high threshold. What this means is when you pick up something that is light, you're going to use the minimum amount of nerve to muscle energy in order to move that thing. Likewise, when you pick up an object that's heavy, you're going to use the minimum amount of nerve to muscle connectivity and energy in order to move that object. So it's basically a conservation of energy principle. Now, if you continue to exert effort of movement, what will happen is you will tend to recruit more and more motor units with time. And that process of recruiting more neurons, more lower motor neurons if you recall from the beginning of the episode, these lower motor neurons are in our spinal cord and they actually dump a chemical acetylcholine on muscle, caused the muscles to contract. As you recruit more and more of these motor units, these connections between these lower motor neurons and muscle, that's when you start to get changes in the muscle. That's when you open the gate for the potential

00:36:58 A Large Range of Weight (30-80% of One Repetition Maximum) Can Be Used

for the muscles to get stronger and to get larger, if that's what your goal is. And so the way this process works has been badly misunderstood in the kind of online literature of weight training and bodybuilding, and even in sports physiology. The Henneman size principle is kind of a foundational principle within muscle physiology but many people have come to interpret it by saying that the way to recruit high threshold motor units, the ones that are hard to get to is to just use heavy weights. And that's actually not the case as we'll talk about the research supports that weights in a very large range of sort of a percentage of your maximum, anywhere from 30% to 80%. So weights that are not very light but are moderately light, too heavy can cause changes in the connections between nerve and muscle that lead to muscle strength and muscle hypertrophy. Put differently, heavyweights can help build muscle and strength but they are not required. What one has to do is adhere to a certain number of parameters, just a couple of key variables that I'll spell out for you. And if you do that, you can greatly increase muscle hypertrophy, muscle size and or muscle strength if that's what you want to do. And you don't necessarily have to use heavy weights in order to do that. Now, I'm sure the power lifters and the people that like to move heavy weights around will say, no, if you want to get strong you absolutely have to lift heavy weights. And that might be true if you want to get

very strong but for most people who are interested in supporting their muscular such that they offset any age related decline in strength, or in increasing hypertrophy and strength to some degree, there really isn't a need to lie about the Henneman size principle which many people out there are doing and claiming that you absolutely need to use the heaviest weights possible

00:38:58 What Makes Muscles To Grow? Stress, Tension, & Damage; Myosin Balloons

in order to build strength and muscle. So I'm going to explain all of this works in simple terms. So first of all, let's just talk about what hypertrophy is and what strength changes in the muscle are. We can make this very simple as well. If this were a muscle physiology class we would talk all about myofibrils and sarcomeres and all that stuff. We're not going to do that. That's not the purpose of today's conversation. If you're interested in that as well as a lot of the other information that I'm going to discuss in more detail, I highly encourage you to check out the YouTube channel and the writings of Dr. Andy Galpin. He's a PhD and a full professor in exercise physiology. He's extremely knowledgeable in this entire area of science-based tools for hypertrophy, how strength and hypertrophy really work. His lab does everything from biopsy on muscles, working with athletes and typical folks as well. A lot of the information that you're going to hear from me in the next 15 minutes or so comes from an extensive exploration of the work that he and his colleagues have done as well as folks like Brad Schoenfeld, another academic who's superb in this whole space of muscle physiology and from a lengthy conversation that I had with Andy, Dr. Galpin prior to this episode. So if we want to think about muscle hypertrophy, we have to ask what is changing when muscles get larger or stronger. And there are really just three ways that muscles can be stimulated to change. So let's review those three ways and talk about what happens inside the muscle. So there are three major stimulate for changing the way that muscle works and making muscles stronger, larger, or better in some way. And those are stress, tension, and damage. Those three things don't necessarily all have to be present but stress of some kind has to exist. Something has to be different in the way that the nerve communicates with the muscle and the way that the muscle contracts or performs that makes the muscle need to change. So this is very reminiscent of neuroplasticity in the brain. Something needs to happen. Certain chemicals need to be present. Certain processes need to happen or else a tissue simply won't change itself. But if those

processes and events do happen, then the tissue has essentially no option except, but to change. So muscles move, as I mentioned because nerves dump chemical onto the muscles but they move because they have these things called myosin and actin filaments. And if you want to read up on this, you can look on the internet you can put the sliding filament theory of muscle contraction if you really want to go deep down that rabbit hole. It's interesting. You can learn about this in a muscle physiology class. But basically, along the length of the muscle you have, what's called myosin. And just think of myosin as kind of like a wire. It's like a bunch of beads and wires that extend across the muscle. I think that's the simplest way to describe it. And the myosin is surrounded by these little beads called actin. The way muscles get bigger is that basically the myosin gets thicker. It's a protein and it gets thicker. So put this in your mind if you're listening to this or even if you're watching it on YouTube, the way to think about this whole actin myosin thing and thing and muscles getting bigger is imagine that you're holding a bouquet of balloons, a bunch of balloons by their strings except you're not holding the strings all at their bottom. So the bouquet isn't nicely arranged. It's not like some balloons that are all up at the top and you're holding the strings down at the bottom. Imagine that one of the balloons that is very close to your hand and other one is a little bit higher up. And so this bouquet is very disorganized. In other words, the string extending out of your hand the strings rather extending out of your hand are all different lengths. And so the balloons are all over the place. That's essentially what myosin looks like in the muscle. And those strings are what we call the filaments, and then the myosin head is the balloon. When you stress a muscle properly, or you give it sufficient tension, or you damage the muscle just enough, there's an adaptive response that takes place where protein is synthesized. And it's a very specific protein, it's myosin. The myosin gets thicker. In other words, the balloons get bigger. So the way to think about muscle growth and the way to think about muscles getting stronger is that those balloons get bigger and the muscle gets thicker. Now, the question then should be as always how does that happen? I mean, the muscle doesn't really know anything about what's happening in the outside world. The way it happens is the nerve, the neuron has to tell the muscle to get stronger. And it does that through what we call a signaling cascade. It talks to the muscle in terms of chemicals. It doesn't whisper to it or shout or Hey, get bigger. What it does it release a certain chemicals that within the muscle, there are certain chemicals released rather that make those balloons as I'm referring to them, the myosin get thicker. So let's talk about the stimulus for doing that. And if already in your

mind, you're imagining oh my goodness, these balloons of muscle are going to get thick, thick, thick, thick, thick, and it's just going to spiral out of control, don't worry about that. People invest a ton of time and energy into trying to make their muscles larger. It's actually much harder for people to do than you might think. But I do want to give one exception because it illustrates an important principle of where we're headed next. Everybody has imbalances in how muscles can grow. How well muscles can grow, or how poorly, or how challenging it is for their muscles to grow. Now, many people who are afraid of like getting too bulky for instance, are afraid of lifting weights. But I think the research shows now that every one of pretty much every age should be doing some sort of resistance exercise even if that's body weight exercises in order to offset this age-related decline in muscle contractile ability, muscle strength, et cetera, improve bone density. There's nothing good about getting frail and weak over time. And people who invest the effort into doing resistance exercises of some kind whether or not it's with bands or with weights or with body weight, really benefit tremendously

00:45:22 Figuring Out Which of Your Muscles Will Grow & Get Stronger Easily (Or Not)

at a whole body level at a systemic level as well as in terms of muscle strength. There is a good predictor of how well or how efficient you will be in building the strength and or if you like the size of a given muscle. And it has everything to do with those upper motor neurons that are involved in deliberate control of muscle. You can actually do this test right now. You can just kind of March across your body mentally and see whether or not you can independently contract any or all of your muscles. So for instance, if you are sitting in a chair or a you're standing, see whether or not you can contract your calf muscle just using those upper motor neuron, sending a signal down and deliberately isolating the calf muscle. If you can contract the calf muscle hard to the point where that muscle almost feels like it's starting to cramp like it hurts just a little bit, that can be extremely painful nor is it going to have no sensation whatsoever, chances are you have very good upper motor neuron to calf control. And chances are, if you can isolate that what they call the brain or mind muscle connection, and you can contract the muscles to the point where it cramps a little bit, that you hold a decent to high potential to change the strength and the size of that muscle if you train it properly. Now, if you have a hard time doing that, chances are you won't be able to do that. If for instance, you focus on your back muscle. Like we all have these muscles called the lat. The latissimus dorsi

muscles, which basically are involved in chin ups and things like that, but their function from a more of a kinesiology standpoint is to move the elbow back behind the body. So it's not about flexing your bicep. It's about moving your elbow back behind your body. If you can do that, mentally or you can do that physical movement of moving your elbow back behind your body and you can contract that muscle hard, chances are that you have the capacity to enhance the strength and or size of that particular muscle because you have the neural control of that muscle. This is a key feature of the neuromuscular system to appreciate as we begin to talk more about specific protocols. Because everything about muscle hypertrophy, about stimulating muscle growth is about generating isolated contractions about challenging specific muscles in a very unnatural way. Whereas with strength, it's about using musculature as a system moving weights, moving resistance, moving the body. The specific goal of hypertrophy is to isolate specific nerve to muscle pathways so that you stimulate the chemical and signaling transduction events in muscle

00:48:11 Getting Stronger Versus Muscle Growth: Distributed Versus Local Effort

so that those muscles respond by getting larger. So there's a critical distinction in terms of getting stronger versus trying to get muscles to be larger hypertrophy per se. And it has to do with how much you isolate those muscles. Muscle isolation is not a natural phenomenon. It's not something that we normally do. When we walk we don't think, okay, right calf contract, left calf contract. No, you just generate those rhythmic movements. And of course, there's no reason for them to get stronger or larger in response to those movements. Let's say you were to do a kind of strange experiment of attaching 30 pound weights to your ankles. And you were to do those movements. Well, if you weren't specifically contracting your calves in each step, there's no reason for the calves to take on the bulk of the work. And you would distribute that work across your hip flexors and other aspects of your musculature. Your whole nervous system seeks to gain efficiency. It seeks to spread out the effort. So you can nest this as a principle for yourself which is if you want to get stronger it's really about moving progressively greater loads or increasing the amount of weight that you move. Whereas if you're specifically interested in generating hypertrophy, it's all about trying to generate those really hard, almost painful localized contractions of muscle. Now, of course, how much weight you use in order to generate those contractions will also impact hypertrophy. But I think most

people don't really understand the mind muscle connection. It sounds like a great thing, but it's actually one of the things you want to avoid if your goal is simply to become more supple or to become stronger. You want to do the movements properly and safely, of course but it's the opposite of hypertrophy where with hypertrophy you're really trying to make that particular muscle sometimes two muscles do the majority, if not all the work whereas in moving force loads in trying to generate activity of any kind like lifting a bar, doing a chin up or something those so-called compound movements involve a lot of muscle groups. If your goal is to be better at those, you want to avoid isolating any one particular muscle. Now, I know this probably comes across as a kind of obvious duh, especially to the folks who have spent a lot of time in the gym aimed at getting hypertrophy. But I think most people don't appreciate that it's the nerve to muscle connections and the distinction between isolating nerve to muscle connections versus distributing the work of nerve to muscle connections, that's vital in determining whether or not you generate hypertrophy isolated nerve to muscle contractions versus strength

00:50:47 How Much Resistance Should (Most) People Use? (30-80% Range) & Specific Goal

and offsetting strength loss which would be distributed nerve to muscle connections. If ever there was an area of practical science that was very confused, very controversial, and almost combative at times, it would be this issue of how best to train. I suppose the only thing that's even more barbed wire of a conversation than that is how best to eat for health. Those seem to be the two most common areas of online battle and the scientific literature has a lot to say about both of those things. Again, my sources for what I'm about to tell you are Professor Andy Galpin and colleagues. I know there are other excellent people out there in the field, but I really trust his work. He does very controlled studies. He spent a lot of time in this space and what's really exciting is that in just the last three years or so, there's been a tremendous amount of information to come out about the practical steps that one can take in order to maximize the benefits of resistance exercise of any kind. So I'm going to talk about those and I'm going to talk about the research. I will provide some links, a couple of the more in-depth tutorials from Dr. Galpin, as well as some of the papers that the information I'm about to tell you stems from. There's a lot of information saying that you need to move weights that are 80 to 90% of your one rep maximum or 70%, or cycle that for three weeks on and then go to

more moderate weights. There are a lot of paths as some people say there are a lot of ways to add up numbers to get a 100. There's a near infinite number of ways to add up different numbers to get to a 100. And what's very clear now from all the literature that's transpired and especially from the literature in this last three years, is that once you know roughly your one repetition maximum, the maximum amount of weight that you can perform an exercise with for one repetition in good form, full range of motion, that it's very clear that moving weights or using bands or using body weight, for instance in the 30% to 80% of one-rep maximum. That is going to be the most beneficial range in terms of muscle hypertrophy and strength. So muscle growth and strength. And there will be a bias if you're moving weights that are in the 75%, 80% range or maybe even going above that 85 and 90%, you're going to bias your improvements towards strength gains. This is true. And if you use weights that are in the 30% of your one-repetition maximum or 40% or 50% and doing many more repetitions, of course, then you are biasing towards hypertrophy and what some people like to call muscle endurance. But that's a little bit of a complicated term because endurance, we almost always think of as relating to running or swimming or some long bouts of activity. So 30% to 80% of one-repetition maximums, it doesn't really seem to matter for sake of hypertrophy, except at the far ends when you're really trying to bias for strength. Now, it is clear, however that one needs to perform those sets to failure where you can't perform another repetition in good form again or near to failure. And there's all sorts of interesting nomenclature that's popping up all over the internet. Some of which is scientific, some of which is not scientific about how you are supposed to perceive how close you were to failure, et cetera. But there are some very interesting principles that relate to how the nerves connect to the muscles that strongly predict whether or not this exercise

00:54:25 How Many Sets Per Week To Maintain Or To Grow Muscle & Get Stronger

that you're performing will be beneficial for you or not. So here's how it goes. For individuals that are untrained meaning they have been doing resistance exercise for anywhere from zero, probably out to about two years, although for some people, it might be zero to one year, but those are the so-called beginners. They're sort of untrained. For those people, the key parameter seems to be to perform enough sets of a given exercise per muscle per week. The same is also true for people that have been training for one or two years or more. What differs is how many sets to perform depending on whether or

not you're trained or untrained. So let's say you're somebody who's been doing some resistance exercise kind of on and off over the years and you decide you want to get serious about that for sake of sport or offsetting age related declines in strength, the range of sets to do in order to improve strength to activate these cascades in the muscle ranges anywhere from two, believe it or not to 20 per week. Again, these are sets per week and they don't necessarily all have to be performed in the same weight training session. I will talk about numbers of sessions. So it appears that five sets per week in this 30% to 80% of the one repetition maximum range, getting close to failure, or occasionally actually going to full muscular failure, which isn't really full muscular failure, but the inability to generate a contraction of the muscle or move the weight in good form. I'll go deeper into that in a moment. But about five sets per week is what's required just to maintain your muscle. So think about that. If you're somebody who's kind of averse to resistance training, you are going to lose muscle size and strength. Your metabolism will drop. Your posture will get worse. Everything in the context of nerve to muscle conductivity will get worse over time, unless you are generating five sets or more of this 30% to 80% of your one repetition maximum per week. So what this means is for the typical person who hasn't done a lot of weight training, you need to do at least five sets per muscle group. Now, that's just to maintain. And then there's this huge range that goes all the way up to 15

00:56:43 10% Of Resistance Training Should Be To "Failure", the Rest Should End "Near" Failure

and in some case, 20 sets per week. Now, how many sets you perform is going to depend on the intensity of the work that you perform. This is where it gets a little bit controversial but I think nowadays most people agree and Dr. Galpin confirmed that 10% not to be confused with the 10% we discussed earlier, but 10% of the sets of a given workout or 10% of workouts overall should be of the high-intensity sort where one is actually working to muscular failure. Now I say not true muscular failure because in theory you have a concentric movement which is the kind of lifting of the weight, and then you have the eccentric portion of muscle contraction, which is the lowering. And eccentric movements because of the way that muscle fibers lengthen and that sliding act myosin that we talked about before, you're always stronger in lowering something than you are in lifting it. But the point being that most of your training most of your sets should

be not to failure. And the reason for that is it allows you to do more volume of work without fatiguing the nervous system and depleting the nerve to muscle connection in ways that are detrimental. So we can make this simple. Perform anywhere from 5 to 15 sets of resistance exercise per week, and that's per muscle, and that's in this 30% to 80% of what your one-repetition maximum. That seems to be the most scientifically supported way of offsetting any decline in muscle strength if you're working in the kind of five set range and in increasing muscle strength

00:58:23 Number of Sets: Inversely Related To the Ability to Generate High Force Contractions

when you start to get up into the 10 and 15 set range. Now, the caveat to that is everyone varies and muscles vary in terms of their recover ability. Depending on how well you can control the contraction of muscles deliberately. And you can actually figure that out by sort of marching, you might take five minutes and just kind of March across your body and mentally try and control the contractions of muscles in a very deliberate way to the point where you can generate a hard contraction. And you may have to move a limb in order to do this, by the way. I'm not talking about just mentally contracting your bicep without moving your wrist. I'm talking about doing that without any weight in hand or any band or any resistance. If you can generate a high intensity contraction using these upper motor neuron to lower motor neuron pathways to muscle, you might think, well I should perform many more sets. But actually, the opposite is true. If you can generate high-intensity muscular contractions using your brain, using your neurons, it will take fewer sets in order to stimulate the muscle to maintain itself and to stimulate the muscle in order to grow or get stronger. So the more efficient you are in recruiting motor units, remember, Henneman's size principle the recruit men have more motor units which isn't just muscles, it's nerve to muscle connections. The better you are at doing that, the more you will recruit these so-called high threshold motor units the ones that are hard to get to, the more you will kick off the cascades of things within muscle that stimulate muscle growth and strength. So if you have muscles that are challenging to contract, it's going to take more sets in order to stimulate the desired effect in those muscles not fewer.

01:00:09 How Long Should Weight Training Sessions Last

If you have muscles that you are very good at generating force within, it's going to take fewer sets. Now, how many sets you are going to have to determine that it's going to depend for those of you that are using like 50% of your one-repetition maximum, because you're doing a lot of repetitions, you might find that three or four, five sets will maintain the muscle. You might decide to do that once at one point in the week and then do it again. So if you're going for 10 sets a week you can divide that among two sessions. You could do that all in one session. The data really show it doesn't matter. There are some differences in terms of whether or not you're trying to generate maximum intensity within a workout or whether or not you want to spread that out. But in general, resistance workouts of any kind tend to be best favored by workouts that are somewhere between 45 minutes and 60 minutes. And generally not longer than 60 minutes because that's when all the things like cortisol and some of the inflammatory pathways really start to create a situation in the muscle and in the body that's not so great for you. So it's not a hard and fast rule. The ax doesn't drop at 60 minutes but it's pretty clear that performing this five to 15 sets per week, whether or not it's in one workout or whether that's divided up across multiple workouts is really what's going to be most beneficial. And please do keep in mind Henneman's size principle and the recruitment of motor units. And remember the better you are at contracting particular muscles in an isolating those muscles, the fewer sets likely you need to do

01:01:35 Training Duration & Volume

in order to get the desired effect. Now, what about people who have been training for a while? If you're somebody who's been doing weight training for a while, the data points to the fact that more volume can be beneficial, even for muscles that you are very efficient at contracting. Now, the curve on this, the graph on this begins again at about five sets per week for maintaining a given muscle group, and extends all the way out to 25 or 30 sets per week. However, there are individuals who for whatever reason can generate so much force. They're so good at training muscles that they can generate so much force in just four or six or eight sets that doing this large volume of work is actually going to be counterproductive. So everyone needs to figure out for themselves. First of all, how often you're willing to do resistance exercise of any kind. And again, it doesn't matter if you're using bands or weights or body weight. For instance, if you're doing chin-

ups chances are unless you are very strong that you're not using weights. You're just using something that you can hold onto. Or if you're doing pushups, some of you will be working in that 30% to 80% of your one-repetition maximum range. It doesn't necessarily mean that you have to be moving weights in a gym for instance. So the purpose here is to figure out what muscles you're trying to train. That's an issue that we'll talk about in a moment. And then it does appear that somewhere between five and 15 sets per week is going to be the thing that's going to work for most people. Now, this is based on a tremendous amount of work that was done by Andy Galpin and colleagues, Brad Schoenfeld and colleagues and others, Mike Roberts. There's a huge group of people out there doing exercise physiology and a small subset of them that are linking them back to real-world protocols that don't just pertain to athletes. So that's mainly what I'm focusing on today. And surely there will be exceptions. Now, if you are going to divide the sets across the week you're not going to do all 10 sets for instance for a given muscle group in one session, then of course, it's imperative that the muscles recover in between sessions. And we are going to talk about recovery both at the systemic level, the whole nervous system and at the local level the nerve to muscle and local even muscle level.

01:03:51 Range of Motion & Speed of Movement; The Key Role of (Upper Motor) Neurons

We'll talk about that in about 10 minutes when we talk about recovery. I do want to mention something very important which is that everything I'm referring to here it has to do with full range of motion. And you might ask, well, what about the speeds of movements? This actually turns out to be a really interesting dataset for generating explosiveness and speed. So for sprinters or throwing sports, or for people that want to generate a lot of jumping power, it does appear that learning to move weights as fast as you safely can, especially under moderate to heavy loads, can increase explosiveness and speed. And most of that effect is from changes in the neurons. It's not from changes in the muscle. It's from changes in the way that the upper motor neurons communicate with the lower motor neurons and generating a pathway, a neural circuit, as we call it, that is very efficient at generating action potentials, which are the electricity within neurons to trigger the muscle. Now, of course there are events that happen from nerve to muscle but the takeaway from that enormous literature, frankly is that if you want to

get faster, yes, it can be beneficial to get stronger. But if you want to dedicate resistance training specifically to jumping higher, to running faster, to throwing further and these sorts of things that learning to generate force with increasing speed is going to be beneficial. On the flip side of that for people that want to get stronger, it appears that the slowing down of the weight as things get harder is a key parameter in recruiting those high threshold motor units. So let me phrase that a little bit differently. Think about a set in the gym or think about a set of pushups or a set of pull-ups. Initially you can move very fast if you like. If you want to generate hypertrophy, the goal really is not necessarily to move super slow but to isolate the muscle and therefore not to use momentum rather than lift weights, as they say, challenge muscles. If you want to get stronger, you're going to be distributing that effort over more muscles and more of your nervous system. For generating explosiveness and speed, it's very clear that learning to generate forces quickly and to move heavy or moderately heavy loads quickly is going to be beneficial because of the way that you train the motor neurons. And of course changes in the muscle. But this could look different for different sports. And obviously you want to make safety paramount. If you're injured, you're not going to be able to train at all for sport or for any purpose that is. And so what this would involve is something like 60% to 75% of a one-repetition maximum, and then in a controlled way moving that as quickly as one can throughout the entire set. And certainly not going to failure because as you approach failure, the inability to move the weight with good form, the weight inevitably slows down. In fact, there are a lot of new technologies now that are focused on informing people of how quickly the bar or weight is moving. I saw an advertisement for this the other day. There are things that people can attach to bars that will literally speak to you as you're doing a set and inform you whether or not you're moving four times more slowly per rep than you were at the beginning. And trying to hone in on the exact speed of movement. In talking to these experts prior to this episode it does appear that for sake of hypertrophy, as long as you're not moving the muscle so quickly that you start to distribute the effort to lots of other muscles, it doesn't really matter because as the set gets harder, the motor units that you recruit will increase the number of neurons that you recruit and the number of muscle fibers and particularly these high threshold muscle fibers will increase. And so it's really only for purposes of hypertrophy that you really need to be concerned about how quickly the weight is slowing down. However, if you're trying to get faster, more explosive and generate more speed and jumping power, throwing power things of that sort, you never really want to use a weight or get to a

portion of the set where you're moving the bar very, very slowly. And I'm sure as I say that some of the exercise physiologists and advanced trainers out there will come after me with pitchforks, which is fine. I'd love to see the literature that shows that low gear slow movements with very heavy weights can indeed improve explosiveness.

01:08:10 Customizing Training; 1-6 Month Experiments; Key Elements Summarized

And that may in fact be the case, but the data that I was able to access was essentially as I described just a moment ago. So as you're probably starting to realize you need to customize a resistance practice for your particular needs and goals. And I certainly am not the first to suggest that people periodize their training. That they do things from anywhere from one month to six months, and to see how it goes and to make modifications as they go. Because the nervous system in particular the neuromuscular system changes very quickly at the beginning of training. In fact, some of the changes that one can see when they first embrace or start resistance training can be very remarkable, but they tend to slow over time. So we've talked about a few principles. The fact that you need to get sufficient volume, you need at least five sets to maintain and you probably need about 10 sets per muscle group in order to improve muscle. That moving weights of moderate to moderately heavy weight quickly is going to be best for explosiveness. The isolating muscles and really contracting muscles hard something that you can test by just when you're outside the training session, seeing whether or not you can cramp the muscle hard will tell you your capacity to improve hypertrophy or to engage strength changes in that muscle. That your ability to contract a muscle hard is

01:09:28 Focal Contractions Between Sets To Enhance Hypertrophy, Not Performance

inversely related to the number of sets that you should do in order to isolate and stimulate that muscle. And there are some other things that can enhance the whole process of building nerve to muscle connections, making them more efficient and generating if you like more strength and hypertrophy. One of them I loath to say I was told is in between set contractions. The other name for this is the people in the gym does typically seem to be guys in the gym flexing their muscles in between sets. And indeed the research supports the fact that contractions have about 30 seconds in between the actual work sets, they're not going to favor better performance on the work sets, if

anything they're going to compromise them. But those hard contractions in between sets for a variety of reasons related to local muscle metabolism as well as what we talked about before which are stress, tension, and damage, they seem to improve stress, tension, and damage and the nerve to muscle contraction in ways that facilitate hypertrophy. In other words, if you see that person flexing in between sets in the gym, provided that they're really isolating that muscle and provided it's one that they ought to be improving, not one of these people that always skips leg day type of people. These people are highly asymmetric although that's up to them, that process of flexing in between sets does seem to improve the nerve to muscle connection and enhance hypertrophy. And I say I was low to say it because nowadays with phones it seems like the end of every set includes a selfie sort of like the 11th rep of every set. I like to joke. It seems like very few people are capable of actually going into the gym and doing a workout without taking a picture of themselves, which I think is fine if that's your thing. Although I must say that the athletes that I know and even the recreational athletes that I know who seem to get the most out of their training and who also seem to get the most out of other aspects of their life, seem to be able to control their phone behavior

01:11:26 The Optimal Resistance Training Protocol To Optimize Testosterone Release

both in the gym and outside of the gym. But that's more of an editorial point there. In an earlier episode, I talked about estrogen and testosterone. And during that discussion, I talked about the use of resistance exercise specifically for increasing testosterone, both in men and in women. And indeed that is a powerful effect of resistance exercise. And indeed it's mediated by the nerve to muscle connections. We talked about that in that earlier episode. I just want to briefly mention that protocol since it's distinctly different from the other protocols I've talked about today. The protocols I've talked about today thus far of explosive movements or of hypertrophy-based training provided the training is 60 minutes or less will cause increases in serum testosterone that's been shown over and over again. And if the session extends too long, past 75 minutes and is of sufficiently high intensity chances are testosterone levels will start to drop and cortisol levels will go up in ways that can be detrimental to recovery and the goals of the training. But that's different than training that's specifically geared toward increasing testosterone. Duncan French, who's one of the directors of the UFC Performance Center, when he was a graduate student at University of Connecticut Stores did some beautiful work. He

and his colleagues found the ideal training protocols for stimulating testosterone release which is something that many people want to do for a variety of reasons. And that involved doing six sets of 10 repetitions even if it requires lightening the weight on one set to the next, with about two minutes 120 seconds rest in between sets. Which if you think of about it is pretty short rest and is pretty darn hard work. Now, what's interesting is that there's a very limited threshold for increasing testosterone. That protocol of six sets of 10 repetitions led to these big increases in serum testosterone. But if people did 10 sets of 10 so just four more repetitions per set, then testosterone did not increase. In fact, you got more of this catabolic cortisol like pathway. You get other benefits from this so-called 10 sets of 10 protocol, but not the testosterone increase and maybe even reductions in testosterone. Now, it's important to point out that that six sets of 10 was done with big compound movements. So things like squats, or deadlifts, or chin-ups or things of that sort. And those were done as single sessions not in concert with a bunch of other exercise, although if athletes are doing that, there's no reason why they couldn't also do other types of training elsewhere in the week. I asked Duncan about this and he mentioned that that done twice a week is probably the maximum that anyone could do that and still maintain this increase in testosterone. It's a very interesting protocol because as a neuroscientist, it's amazing to me that six sets of 10 repetitions with something, causes a distinctly different result in terms of hormone output than 10 sets of 10 of the exact same movement. And it speaks to the exquisite way in which nerve to muscle connections dictate the whole physiology of your entire system. If there's a theme that I really want to bring forward today is that weight training or resistance training of any kind is really used for either systemic effects. 10% of training done where you're feeling that burn which means lactate will be present and sending signals to your brain, and your heart and your liver that are beneficial or isolating muscles which may also generate a kind of a lactate which is associated with the burn result but that isolation of muscles distinctly different. So systemic versus isolated. Those are the two general ways in which resistance training can be applied. So I just wanted to mention that earlier protocol because it's well supported by the literature. If you were to incorporate that protocol, you might ask, well, then can you do any other weight training during the week? And sure, of course you can provided you're recovering. So let's talk about how you know if you're recovering. How you know if a muscle is recovered and how you know if your whole system is recovered. Because recovery is what dictates whether or not you can come back and do more work of a different kind. Meaning, I don't

know, you do a leg training one day, can you and should you come back and do the upper body training day? And it dictates whether or not you'll see any improvement from session to session at all.

01:16:00 How Quickly To Complete Repetitions; Interset Rest Times & Activities; Pre-Exhaustion

Before I talk about recovery I just want to make sure I nailed down the details that I was able to extract from the literature and from my conversation with Dr. Galpin. If you're wondering how quickly to perform repetitions for sake of hypertrophy or strength gains, anywhere from a half a second per repetition all the way up to eight seconds per repetition, it doesn't seem to matter. Again, if you're thinking about explosiveness or building speed, or you're specifically using resistance training to build endurance, that's a separate matter. We talked about explosiveness and speed. I'll talk about endurance in a few moments. We also talked about in between set contractions the so called selfie effect of people flexing a particular muscle, isolating a particular muscle between sets, just want to mention that would be a terrible thing to do if your goal is performance on sets. So moving a particular amount of weight. That's actually going to diminish the amount of weight that you can move. It's going to enhance muscle growth and it's going to enhance the nerve to muscle isolation of that particular pathway. So again, that flexing between sets is going to favor hypertrophy, not performance. If you're trying to get stronger, you're trying to move more weights, you're trying to distribute work, and you're trying to do maybe skill training with resistance then flexing between sets is absolutely the wrong thing to do for obvious reasons you're fatiguing the muscle further. Just remaining still or walking around a little bit has been shown to be beneficial in terms of moving some of the lactate out of the muscle as well as just recovering between sets. Now, how long to recover between sets, is a question. For the testosterone protocol, Duncan French and colleagues found that it was about two minutes keeping that really on the clock, two minutes not longer. For hypertrophy and for strength gains, it does seem that resting anywhere from two minutes or even three or four, even five or six minutes can be beneficial. And if you're interested in expanding the volume of work that you can do in a given session at high capacity at high intensity, with a given weight, please see the episode that I did on cold and performance about supercharging performance which is based on the work of my colleague Craig Heller in the Biology

Department at Stanford, which talks about Palmer Cooling, about how you can cool the core of the body best through the palms using these particular venous portals that are only present in your hands. People are now doing this with ice packs or with gel packs. There are a number of different ways one can do this. I talk all about that in that episode. It allows you to do more repetitions and more work at a given weight over time. So rather than getting 10 repetitions and then eight and then seven and then six through proper use of palmer cooling, one can do 10, 10, 10, 10, and even add sets. And that's one way that one can accomplish higher volume work without having to drop the weight considerably. So that's where you can hit that really sweet spot if that's your goal of getting strong and generating some hypertrophy. Because as soon as you have to drop to lighter weights, then you're shifting more towards hypertrophy and endurance and less toward strength of any given muscle. So check out that episode. The last thing besides between set contractions and whether or not you're distributing work or whether or not you're really trying to isolate muscles is this notion of pre-exhausting muscles. It's been shown over and over again that for instance, if you want to generate force in a given muscle and really isolate that, doing the isolation work before a compound movement. So this would be leg extensions the thing where you sit and you extend your toes up toward the ceiling. Leg extensions before squats will allow the squats to target that muscle group more effectively. And that makes perfectly good sense based on the Henneman's size principle and fatiguing motor units. It should be obvious why that's the case. But of course that's going to be anti performance in terms of how much weight you can lift, and maybe even the form that you can maintain when you move to the bigger compound movement. So you really have to ask yourself a number of questions. How good are you at isolating a given muscle? Therefore, how many sets do you want to do? How often are you willing to train therefore, how many sets are you going to do in a given session versus how many are you going to distribute across the week? Are you aiming for performance? Are you going to distribute that work across the nervous system and musculature? Are you trying to move weights? Are you trying to challenge muscles? If you're trying to challenge muscles, then you really want to focus on things like this pre exhausting the isolation of a muscle before the compound movement. Your performance on compound movements will absolutely suffer but your ability to isolate that muscle and generate hypertrophy through the accumulation of larger myosin, those bigger balloons, will benefit.

01:20:43 Tools To Determine If You Have Recovered From Previous Training: Local & Systemic

And once again, if you're trying to get faster than the speed of the movement really matters. So how do we know if we've recovered? How can we test recovery? And this is not just recovery from resistance training, this is recovery from running, recovery from swimming. Up until now I've been talking about resistance training more or less in a vacuum. I haven't even touched on the fact that many people are running and they're doing resistance training or they're swimming and they're doing resistance training. It's not simply the case that if a given muscle is fatigued you can just work other muscles. Because even if you've beautifully isolated a muscle, let's say you have incredible abilities to isolate just your quadriceps for instance and you do a workout where you isolate your quadriceps you do your six sets of intense work or maybe use palmer cooling, and you're able to do 12 sets of intense work and you're done, and that muscle group the next day is certainly not going to be recovered unless you're somebody who's extraordinary at recovery or you're enhancing your recovery through chemical means which we'll talk about at the end. Well, you can assess systemic recovery meaning your nervous system. And your nervous system's ability to generate force both distributed and isolated through three main tests. And fortunately, these tests are very simple and two of them are essentially zero cost, require no equipment. HRV, heart rate variability has made its way finally into the forefront of exercise physiology and even into the popular discussion. I've talked about HRV before. How when we exhale, our heart rate slows down because of the way that our diaphragm is connected to our heart and to our brain and the way our brain is connected to our heart. When we inhale our heart rate speeds up and that is the basis of heart rate variability. Heart rate variability is good. It means that you're breathing properly, and when I say it's good it means you want a lot of heart rate variability. You don't want a heart rate that is high or low consistently over time. That might come as a bit of a surprise for you endurance athletes, who probably are trying to accomplish your endurance work at a steady cadence to really hit that nice sweet spot where you're breathing rhythmically, your heart rate's going rhythmically. You're in that steady heart rate, and then away from exercise, you have a nice low heart rate as they say. Well, nice low heart rate isn't necessarily always so nice. Turns out the introducing bouts of increasing your heart rate during exercise and even through your waking day, through stressful events even is provided their brief is beneficial. A good nerve to heart

system benefits from being able to increase heart rate and decrease heart rate. Heart rate variability is good. So you don't want high heart rate, you don't want low heart rate all the time. But heart rate variability is difficult for a lot of people to measure. There are some devices that will allow you to do that. Various watches and devices. There are more devices becoming available all the time. Hopefully soon, some that are integrated with your phone that involve no contact or anything on your body. But those do carry some costs and they are not perfect yet. The measures of heart rate variability that one can use while in movement are still in that phase I would say of technology development where everyone isn't using them, let's leave it at that. There are two measures however, whether or not you recovered that you can use first thing in the morning when you wake up, maybe after five, 10 minutes, if you like, but ideally right when you wake up in order to assess how well recovered you are and therefore whether or not you should train your whole system at all that day. The first one is grip strength. Grip strength, the ability to generate force at the level of squeezing the fist or squeezing down on something, might seem like kind of a trivial way to assess recovery but it's not because it relates to your ability to use your upper motor neurons to control your lower motor neurons and to generate isolated force. So that's really what you're assessing when you do that. Some people will use one of these grip tools or Costello has this toy that's shaped like a donut and it's this hard rubber. And I've tried this before. If I've been working really hard, not sleeping very well, or I've been training a lot any one or combination of those things, my grip suffers. I can't actually squeeze that thing down as much as I can Costello because he was born with like a 24 inch neck even though he's never touched a weight somehow he can just clamp down on that thing, and he can turn it into a pancake with ease and he likes to chuckle while I struggle with this thing. But on a good day, I can squeeze this thing so that I eliminate the hole in the donut so to speak. You can also take a floor scale and squeeze the scale and see how much force you can generate. I would do that as a baseline to establish what you can do when you're well rested. And then if you do that in the morning, you can see whether or not you're able to generate the same amount of force or you could use over the rubber donut or something. A lot of this is very subjective with a scale you're really trying to assess whether or not you can generate the same amount of force. If you start seeing a 10% or 20% certainly reduction in that that's concerning, it means that your system, your nervous system as a whole it's not necessarily fatigued, is that the pathways from nerve to muscle are still in the process of rewiring themselves in order to generate force. And you might think, well, I train one

muscle group one day. Why am I having a hard time doing this for a completely different muscle group? It doesn't make any sense. But there's something about the upper motor neuron to lower motor neuron pathway generally that allows you to use something like grip strength as a kind of a thermometer, if you will of your ability to recover. So look for your ability to generate force in grip when you first wake up. It's not going to be as good as it is at 3:00 PM after a cup of coffee and a couple meals but the point isn't performance overall, the point is to assess whether or not you're getting better, worse or the same from day to day. The other one that's really terrific

01:26:33 Carbon Dioxide Tolerance Test For Assessing Recovery

and the Andy Galpin's group is using. And I'm delighted about this because it relates to something that my lab is very excited about as well is carbon dioxide tolerance. So this is a really interesting tool that endurance athletes, strength athletes I think can all benefit from. In fact athletes and people of all kinds. Even if you're not an athlete, even if you're not exercising at all, there's a good question of whether or not your system as a whole is doing okay or not. We rely on the thermometer. Do we have a fever or not? We rely on subjective things. Do I feel good or not? Am I digesting well or not? Those are all subjective. The carbon dioxide tolerance test is, its objective in that it measures your capacity to engage the so-called parasympathetic arm of your nervous system which is the calming aspect of your nervous system. And it measures your ability to consciously control a particular skeletal muscle, which is your diaphragm. So here's how you do the carbon dioxide tolerance test. You wake up in the morning. If you have to use the restroom first, do that, but try and stay away from your phone. If you have your phone, put it on airplane mode, go to the timer or use a hand watch or some other way of measuring time, stay off social media for just a few seconds. It'll be okay. And what you're going to do is you're going to inhale through your nose as deeply as you can, you can do this lying down, sitting, whatever inhale through your nose and then exhale all the way. So that's one. You're going to repeat that four times. So inhale, exhale, inhale, exhale inhale, exhale, inhale, exhale four times. And ideally you're inhaling through the nose and you're exhaling through the mouth. That's just the beginning of this carbon dioxide tolerance test. Then you take a fifth inhale as deep as you can through your nose. Fill your lungs as much as you can, and if you can try and expand make your stomach go out while you do that, that means that your diaphragm has really engaged.

So you're inhaling as much as you possibly can. Then hit the timer and your goal is to release that air as slowly as possible through your mouth. So it looks like you have a tiny, tiny little straw in your mouth and you're letting it go. As slowly as you possibly can. Measure what we call the carbon dioxide blow off time or discard rate. I know you can all sit with lungs empty after you eliminate all that air, but don't lie to yourself. Don't stop the timer when you've been sitting with your lungs empty for a while, stop the timer when you are finally no longer able to exhale any more air. So you do inhale, exhale, inhale, exhale, inhale, exhale, inhale, exhale slowly. I just said it quickly for sake of time then you can do this fifth big inhale through your mouth, and then [deep exhale] And I'm not going to do it for the full duration. And then you're measuring that time. Your carbon dioxide discard rate will be somewhere between one second and presumably two minutes. Two minutes would be a heroic carbon oxide discard time. 30 seconds would be more typical. 20 seconds would be fast. If your carbon dioxide discard time is 20 or 25 seconds or less, you are not necessarily recovered from your previous days activities. There's ways to push through this but hold onto that thought for a moment. If your carbon oxide discard time is somewhere between about 30 seconds and 60 seconds, you are in what we would call kind of the green zone where you are in a position to do more physical work. And if your carbon dioxide discard time is somewhere between 65 and 120 seconds, well then you have almost certainly recovered your nervous system. I'm not talking about the individual muscles but your nervous system is prepared to do more work. And Andy's Lab has great data on this as it relates to exercise physiology. I think that story should be out in the not too distant future. My lab has been using carbon oxide discard time to look at anxiety and recovery from bouts of anxiety. So two totally independent projects but using the same measure. So you've got HRV, which requires some technology usually. You've got grip strength, which you can assess subjectively or you can use a floor scale and now you have carbon dioxide tolerance. You want to do this in the morning when you wake up and keep track just write down in a little book, or maybe just keep tracking your mind of your carbon oxide discard time. If you find that your discard times are dropping even if they're in the 42nd range or 52nd range, but normally you can do 75 seconds or 120 seconds. If they're starting to drop by anywhere from 15% to 20%, you're veering in the direction of not recovering. And I'm really keen on this tool because everybody has different recovery abilities. Some people are eating really well and sleeping really well. Some people have minimal stress or can buffer stress really well. Other people they dissolve into a puddle of tears if they read one text

message that's troubling or whatever. And I realize, and I say that with sympathy, I realize people have varying levels of stress and demand in their life. It's just to to prescribe an entire protocol that says, okay, yes you should train today and this is exactly what you should do. No, you shouldn't. Use carbon dioxide discard rate because a, it's valuable, it's informative. b, it's zero cost and c, it's something you can track objectively over time. And that's really the key. And I'd be remiss if I didn't say that what carbon dioxide discard rate is tapping into is your ability to mechanically control your diaphragm certainly that's one aspect of it, but that relates in a very direct way to your ability to put the brake on your stress system.

01:32:43 The Way To End Every Training Session. How To Breath Between Sets For Performance

To engage the so-called parasympathetic or calming arm of your autonomic nervous system. And another thing that Andy Galpin's group is testing is at the offset of training after your run, after your weight training session, maybe even after your plyometrics session, we didn't really talk about jumping and throwing and that sort of thing. Maybe we'll talk about it in a future episode. But they and other groups, including some elite athletes and other groups that are very interested in physical performance are using a tool where they deliberately disengaged for five minutes at the end of training. They deliberately engage this calming or parasympathetic arm of the nervous system. And you can do that through any number of different tools. I'm a big fan of respiration tools 'cause they're always available to you. Your breathing is always there. I talk about some of these tools in previous episodes but you could use things like non sleep deep rest and SDR at the end of a training session. You could do 10 physiological size, double inhales through the nose followed by long exhales, that will definitely engage the parasympathetic nervous system at the end of training. So rather than finish your training session and then just hop onto your phone, serious athletes and people who are serious about recovery initiate that recovery at the very end of their training and they start to kickstart that recovery process rather and they measure CO₂ tolerance in the morning. So there are several groups that are doing that. In fact, I know several groups because I'm working with them that are using physiological size between sets in order to recover their nervous system and maintain nerve to muscle contractibility. Maintain focus throughout their training session enhance their focus by doing a few physiological size.

So double inhale, exhale in between sets. So they're getting very focused and very intense about their strength work or explosiveness work, muscle isolation work during their sets. And then in between sets, they're deliberately disengaging the nervous system, and then they're re-engaging it again. So I just wanted to emphasize that. So recovery is a complex process.

01:34:46 How & When To Use Cold Exposure To Enhance Recovery; When To Avoid Cold

It's got a lot of things but the CO2 tolerance set should be a valuable tool. Now, another tool for recovery that people are very excited about is the use of cold and the ice bath. And this is important. If you are somebody who uses cold through cold shower, or ice bath, or jumping in a lake, or a river whatever it is that used to generate cold as a recovery tool, you should be aware that there are data starting to emerge that if your goal is recovery or strength improvements, using cold within the four hours following a workout. I'm not talking about palmer cooling, I'm talking about whole body cooling or cooling from the neck down. Yes, it will reduce inflammation. Yes, it will reduce the amount of delayed on muscle soreness one readout of how intense or damaging a given workout was not the only readout, but it does seem to interfere with some of the things like mTOR pathways, the mammalian target of rapamycin pathway and other pathways related to an inflammation that promote muscle repair and muscle growth. Remember, stress, tension, and damage or the stimulus for nerve to muscle connections to change and for muscles to get bigger, stronger, and better. And so if you're getting into the ice bath after training or taking a really cold shower after doing resistance training, you are likely short-circuiting the improvements that you're trying to create. Now, athletes who are trying to recover quickly so that they can get back into more training sessions, or let's say you're somebody who doesn't really want to gain much strength or hypertrophy and you're mainly focused on endurance and you want to do more endurance work and you've been weight training, well then exposing yourself to cold can be beneficial, but you're not going to get as great of benefits from the resistance training. In other words, cold after resistance training seems to short circuit some of the benefits of that resistance training. There are some other things that can short circuit the benefits

01:36:37 Antihistamines & Anti-Inflammatory Drugs: Can Be Problematic/Prevent

Progress

of resistance training as well. One of those is anti-histamines. Some interesting data were published recently. I believe it was in scientific reports, yes that showed that anti-histamines can prevent some of the benefits of cardiovascular exercise of endurance type work as running, swimming of fairly long duration or even sprint type work, as well as inhibit some of the processes associated with resistance training. Remember, it resistance training or endurance training, that's a stimulus for stress and the adaptation to that stress is how you get better. That you can run further, faster, lift more weight, hypertrophy the muscle, et cetera. So anti-histamines can be a problem. Obviously don't compromise your ability to breathe completely, but anti-histamines generally work by blocking what are called mast cells and M-A-S-T. Mast cells are really interesting cells that we'll talk about in our month on neuro immune function. They travel in the bloodstream and these little packets that burst open it sites of inflammation. Muscle damage and inflammation is a signal that something needs to change. And so taking it to histamines it appears can disrupt some of that inflammatory process. So you actually want inflammation during and immediately after a workout, then you want to bring inflammation down later and I'll mention how to do that. The other thing are non-steroid anti-inflammatory drugs you know their trade names. These are painkillers that many people take. Those as I've mentioned in a previous episode can interfere with the benefits of endurance training and the benefits of resistance training. In addition to that, they block pain signals and pain is a very good signal that you might be doing something wrong. And so while nobody likes to be in pain, I suppose there are probably a few people out there like to be in pain, but that's a different story but nobody likes to be in pain. The non-steroid anti-inflammatory the NSAIDs as they're called, and the anti-histamines seem to prevent a lot of the gains the improvements in endurance, strength and size that people are specifically using exercise for. So be cautious about your use of non-steroid anti-inflammatory drugs

01:38:42 Foundational Supplements For Recovery: EPA, Vitamin D3, Magnesium Malate

especially within the four hours preceding or the four hours following exercise. So I hope you're starting to get the picture. In order to change the nerve to muscle connectivity in

ways that will better serve you, you need a stressor during the actual training which particular stressor depends on your training goals. But that stressor is almost always going to be associated with inflammation, and then after the training, you want to try and get into a state of reduced inflammation. And that's why you would do some sort of protocol non sleep depressed which we will link to in our caption or perhaps you would use the hypnosis app that we've talked about before Reveri, R-E-V-E-R-I.com. There's a great app for accessing deep rest states or the physiological side to try and get your system to calm down after training. There are also tools that one can use to reduce inflammation at a kind of foundational level away from training. And these are tools that I've talked about many times before, but I'll just restate them again. The kind of Golden Three according to Andy Galpin and the ones that he recommends are sufficient omega-3s again, that can be accomplished through diet, through whole food intake or through supplementation or both. So in general, getting above a 1,000 milligrams of EPA per day to keep inflammation low or relatively low. Vitamin D and in some cases, magnesium malate. Magnesium malate seems to be particularly effective in offsetting delayed onset muscle soreness. Soreness itself is not required for improvements in strength, improvements in explosiveness, improvements in hypertrophy. That's a myth. Now, if you do experience delayed onset muscle soreness, chances are you stressed that particular muscle pretty well or even maybe to well, maybe you stressed it too much and you need longer recovery. There's a total debate out there about whether or not you should train again when a muscle is still sore. I think the general takeaway is, no that means it's not recovered. And there are things of course like massage, like fascial release and things of that sort sauna, cold that can perhaps accelerate the movement from soreness to not sore. But in general, the omega-3, vitamin D, and magnesium malate trio seemed to be an effective way to reduce inflammation at kind of a systemic level. But remember you want inflammation provided you're not damaging the muscles so much

01:41:08 Ensuring Proper Nerve-Muscle Firing: Sodium, Potassium, Magnesium

that you're injured during the training session because that's the stimulus for change in those muscles. I want to talk about a few other things that support the process of nerve to muscle communication and touch on some of the things that a lot of people are doing to try to "enhance their workouts" and evaluate whether or not those are in fact

enhancing workouts or not. Because weight training, unlike a lot of other forms of exercise has a unique aspect to it, which is this feature that I guess some people call it the pump which is the fact that blood goes into the muscle when you train, it's the only gun of training where you actually get a window into what the result might actually look like before you actually accomplish that result. So if you think about when you go out for a hard run and let's say you go out for a two mile run, let's say your goal is to break you want to do a sub ten two mile. Actually, when I went to university I was running cross country, my senior year of high school and I wanted to walk on for the cross country team. And so I went out there and turned out you had to do a sub 10, two mile. And I think the best mile I ever ran in high school was a 457, which isn't terrible. I can't do that now. It's not even close to what the best high school athletes can do now. But that would have meant doing it back-to-back. So it was sub 10 minute two mile didn't even come close. I told Costello this story the other day and he just kind of laughed at me. He was like, why would you even want to run two miles? Because Costello is built almost exclusively of these type two fast twitch muscles they're designed for moving objects. He's incredibly strong. He has been since he was a puppy. I mean that dog could probably drag a tractor if he wanted to, but he can't really go far. Whereas a Greyhound or a Whippet or some of these other sight hounds or scent hounds can go, go, go. They have a higher percentage of the so-called slow-twitch muscle fibers. They are much better at endurance. So a sub-10 two mile would have been very, very challenging, no chance I could have done that. I don't think even with a lot of training. But let's say that you want to improve your performance in a given type of exercise. Let's talk about some of the things that seem to work across the board to improve strength, improve hypertrophy, and improve nerve to muscle communication and performance. The first thing that's absolutely key for nerve to muscle communication and physical performance of any kind might not sound that exciting to you but it is very exciting. And that's salt. Nerves cells, neurons communicate with each other and communicate with muscle by electricity. But that electricity is generated by particular ions moving into and out of the neuron. And the rushing in of a particular ion, sodium, salt is what allows nerve cells to fire. If you don't have enough salt in your system your neurons and your brain and your nerve to muscle communication will be terrible. If you have sufficient salt, it will be excellent. How much salt will depend on how much water you're drinking, how much caffeine you're drinking, and how much food you're ingesting. And whether or not you're taking any diuretics how hot it is, et cetera, how much you're sweating. So you want to

make sure that you have enough salt, potassium and magnesium in your system if you want to perform well. I realized that salt isn't very glamorous performance tool but it is a vital. Its absolutely vital. And the endurance athletes and the people that train in high heat can speak to the fact that when your electrolytes are low, your brain doesn't function, your body doesn't function nearly as well. In fact, even for mental work, for studying and for writing and for doing math and coding, doing analytic work of any kind, even a hard conversation that's important to you, having sufficient electrolytes is really going to help and being low on electrolytes won't help and just drinking water won't help because you need electrolytes.

01:45:00 Creatine: Good? How Much? Cognitive Effects. Hormonal Considerations:
DHT

The other thing that's been shown over and over again, a numerous well-controlled studies to improve muscle performance is creatine. Early on there was a lot of controversy about creatine but there are many studies if you want, you can go to this website that everyone now knows I love which is this free website examined.com that there are no fewer than 18 studies there. 66 studies... So 18 studies supporting that muscle creating content can be increased by ingesting creatine. How much creatine? Well, I asked the experts and they tell me that for somebody who is about 180 pounds, five grams a day should be sufficient or so. Heavier than 180, so if you got like if you're a 220 pound or 230 pound person, 10 to 15 grams of creatine. People lighter than 180 pounds maybe three to five grams of creatine or even one to three grams. Creatine is a fuel source for early in bouts of activity for high intensity activity. It is also a fuel source for neurons in the brain and it can have some cognitive enhancing effects. So creatine is a very interesting molecule. Early on when it was released as a supplement, it was thought that you had to load it in higher dosages for a few days and then maintain it at lower dosages. So you'd take 20 or 30 grams a day then back off to five or 10. It doesn't seem to be the case that you can get all the benefits from taking the dosages at the low level. I just mentioned a few moments ago as they relate to body weight throughout. So salt and electrolytes absolutely key. You need those present. You need to be well hydrated. Creatine seems to have a performance enhancing effect. There are 66 studies, 66 showing that power output is greatly increased anywhere from 1%2 to 20%. And this is sprinting and running and jumping as well as weightlifting by creatine. The

ability to hydrate your body is improved by creatine because of the way that it brings more water into cells of various kinds. As an indirect effect, it can help in increasing muscle mass because of the way that it brings more water into muscle and probably also because of the way that if you get stronger, you can generate more force and generate more hypertrophy. It reduces fatigue. Seven studies have shown that it reduces fatigue. There are even some interesting effects on improving cognition after traumatic brain injury. Although that's a serious medical condition in situations you absolutely should talk to a board certified physician before adding anything or taking anything out of your current regimen. There are a few other effects that are interesting and notable, but the big ones are the ones that I referred to before about increased power output, et cetera. And I just want to emphasize that creatine can increase this hormone that we talked about in the testosterone episode, dihydrotestosterone which is testosterone converted by five alpha reductase into dihydrotestosterone. It's the more dominant androgen in humans. Leads to increases in strength and libido and so forth. It also can increase male pattern baldness. Some people, not everybody experience some hair loss with creatine other people don't. Some people experience accelerated beard growth because basically [mumbles] has the opposite effect on hair follicles on the face as it does on the scalp, some people don't. Women who ingest creatine there are essentially no data showing that it increases hair loss or facial hair growth, but of course, everyone is different. So you can go to examine.com. You can explore those studies. So creatine definitely a powerful performance enhancing molecule. The other one, one that personally I've never tried but that seems to have a very strong and well-supported effects is beta-alanine. Now, beta-alanine is interesting because when you hear about weight training you think about heavy deadlifts and bench presses all that kind of stuff that people are doing. But beta-alanine seems to support exercise that is of slightly longer duration. So a mix of anaerobic and aerobic type movement. These are physical performance in the 60 to 242nd range. So you can use your mind and kind of figure out. Things that weights that limit you to 8 to 15 repetitions. Cardiovascular exercise of the sort like rowing or sprinting. So interval work, it seems to help with that kind of work. So we're not talking about long runs, we're not talking about heavy deadlifts. The standard dose is somewhere between two and five grams, again, as always check with a doctor, make sure these things are safe for you. I'm not responsible for your health. You are. I don't say that just to protect me. I'd say that also to protect you but it really seems to improve muscular endurance, improve anaerobic running capacity, reduce fatigue.

There are even some interesting effects on reduction of body fat and improvements in lean mass. So creatine, beta-alanine, electrolytes, these are kind of the core three things that seem to improve performance and are well supported by the scientific literature. And in the earlier episode on supercharging performance we talked about palmer cooling. That's certainly a performance enhancing tool. It's nothing you ingest your cooling your palms in a very specific way. That's very powerful.

01:50:12 Beta-Alanine, Beet Juice; Note About Arginine & Citrulline & Cold Sores

Now, what about for longer duration bouts of exercise? We've mainly been focusing on resistance training, but what about for long runs, long swims, these kinds of things? Well, it does seem that juice and ingesting things like arginine and citrulline can improve performance for those long bouts of exercise that's mainly going to be due to effects of those compounds on vasodilation. It's going to open up the vasculature and allow more blood flow. Do note that things like citrulline and arginine can have some side effects if you will. They can increase the likelihood of having herpes cold sore outbreaks on the mouth. The arginine is in the pathway by which I don't know if people know this, but the herpes virus lives on neurons of the trigeminal nerve that innervates the lips and the eyes and the mucus membranes of the face. So this is the herpes type 1 simplex virus. The virus lives on those neurons and then periodically inflames those neurons, and that's what leads to the cold sores seems like arginine and citrulline can lead to increases in cold sores and canker sores, and outbreaks of those kinds. So you want to be aware of that. That's not everybody, and not everybody is caring HSV-1, just be aware that I think it's now 80% or 90% of people by time they're 12 years old, they've contracted HSV-1. It's very contagious and typically one outbreak, and then only under conditions of stress or heightened arginine or citrulline ingestion we'll have them later. Again, this is not necessarily an STI, a sexually transmitted infection. This is an infection that is passed very easily from mucous membranes, just in terms of touching objects

01:52:00 Nutrition: Protein Density: Leucine Thresholds; Meal Frequency

and things of that sort. Very common in the general population. Any discussion about muscle and muscle performance would not be adequate if we didn't mention something about nutrition, but rather than have a whole discussion about nutrition, 'cause there's

lots of information about that online, for instance, if you want to gain muscle that you need to have a calorie surplus of about 10 to 15%. You could have a calorie surplus of more. If you want to avoid gaining weight then you would not create a calorie surplus, et cetera. You can find all that information online. That's not what this podcast is really about. We had a month where we talked a lot about hormones and food and moods. We talked about foods, but more as they relate to the nervous system. When it comes to supporting muscle. So supporting the synthesis of larger what I called myosin balloons, it does seem that ingesting 700 to 3000 milligrams of the essential amino acid leucine with each meal is important. Now, that does not necessarily mean from supplements. In fact, most people recommend that you get your protein, you get your amino acids, including your essential amino acids and your leucine from whole foods. High quality proteins aren't high density proteins. What do you mean by that? Well, it is true that a lot of sources of protein are found in things like beans and nuts and things like that that all the essential amino acids can be found there but per unit calorie, if it's in your practice, if it's in your ethics to ingest animal proteins, it's true that for instance, 200 calories of steak or chicken or fish or eggs will have a higher density of essential amino acids than the equivalent amount of calories from nuts or plants. That's just simply the way it works. So for the vegans and vegetarians I'm certainly, I'm not saying there's no way that you can support muscle growth. You absolutely can. Some of them might want to supplement leucine but this 700 to 3000 milligrams of leucine per meal is one of the best ways that's been shown to support the synthesis of more myosin if your goal is hypertrophy and it's also the way that you would support muscle repair if your goal is strength. So that's specifically geared towards muscle hypertrophy and strength. And I encourage you to think about this protein density issue. And whether or not you ingest animal proteins or you don't, to think about whether or not you're getting sufficient essential amino acids, especially leucine. Now, many people have addressed the question of whether or not you need to eat six or seven times a day. It turns out that you don't that's kind of the old school thinking that you need to eat very frequently. I think for certain athletes were very active for drug assisted meaning people that are enhancing their testosterone levels to super physiological levels, where they are experiencing very heightened levels of protein synthesis and they can utilize all that. That might make sense. Again, I'm not supporting the use of those performance enhancing drugs but there are people doing that. And that's one of the reasons why they eat so frequently. And so much protein for typical people who are not doing that, I imagine most of you are not. Then it does appear that

you need to eat but you don't need to eat six or seven times a day. It does seem like not eating once a day is also important. So somewhere between one meal a day and six meals a day, lies the more reasonable two or three or maybe four times a day. I think that a whole discussion about this is warranted and we'll have this discussion with Dr. Galpin at a future time of whether or not eating protein more frequently can enhance this myosin synthesis. But I think the simple takeaway from the literature that I was able to extract and from my discussion with him is, eating two to four times a day, making sure you're getting sufficient amino acids in a way that's compatible with your ethics and with your nutritional regimen

01:55:54 Why Hard Workouts Can Make It Hard To Think/Do Mental Work

is going to support muscle repair, muscle growth strength improvements, et cetera, just fine. There's one more thing that I'd like to cover which is the relationship between particular kinds of exercise and our ability to think and perform cognitive functions. We all hear that exercise is so vital for our brain that it supports our brain health and our body health. And indeed that's true provided it's done correctly. However, many of us are familiar with the experience of going for a run or going for a swim or working out hard in the gym, and then not being able to use our brain to be essentially useless for cognitive functions for the rest of the day. I discussed this with Dr. Galpin this morning, and I learned something very interesting, which is that hard bouts of exercise of the sort where you're training near failure or you're generating focused muscular contractions, for obsession that lasts anywhere from, I don't know, 30, 45 minutes, maybe 60 minutes or a long run where you're engaging in some interval training during that run, after exercise, there's a reduction in oxygenation of the brain. So there's actually a quite significant dip in the amount of oxygen that your neurons are getting and therefore your ability to think. So it's important that you control the intensity and the duration of your training sessions so that you're still able to do well in life and lean to life the way you need to, because I'm guessing most of you are not in a position to just prioritize your physical training you also need to use your minds. I'm certainly familiar with wanting to get exercise

01:57:25 Leveraging Weight Training & Rest Days To Optimize Cognitive Work

but also the requirement of needing to perform cognitive work throughout the day. It also

turns out that you can leverage something interesting about exercise and nerve to muscle work in ways that can benefit cognitive function and focus. And it has to do with the way that your body and your nervous system predict bouts of intense focused effort. So let's say you're doing resistance training two or three times a week, maybe even four times a week and you're doing it consistently at a given time. There are clocks, literally biological clocks within the liver and within the brain that learn to predict that focus and that intense work. If you are trying to get intense cognitive work done, you might try scheduling that cognitive work on the days when you don't do physical training at the same time when you normally would do that intense, focused physical training. Because the systems of the body that generate acetylcholine release and other neuromodulators, the systems, of the body and brain that generate focused effort, those are on this sort of clock mechanism in a way that you likely will find that after just a week of training at regular times you will be able to focus readily on other things when you're not training provided you do it during the period of time of day when you normally would train. So is kind of an indirect positive effect. You're harnessing the focus and the expectation of focus in your nervous system for that particular time of day. And of course, we'd be remiss

01:58:58 What Time Of Day Is Best To Resistance Train?

if we didn't talk about time of day for training. It turns out that whether or not you train in the morning or in the afternoon, it doesn't really seem to matter for sake of things like hypertrophy and strength, et cetera. Everyone seems to have a time of day that they prefer to train. I've said before and their reasons based on body temperature rhythms and cortisol release that training 30 minutes, three hours or 11 hours after your normal waking time can be very beneficial and can provide a sort of predictability or regularity to when your body will be ready to train and best apt to train well. There is some evidence that training in the afternoon is better for performance, whereas training for body composition changes and strain changes, et cetera doesn't really matter when you train.

01:59:40 More Information Resources, Subscribing (Zero-Cost) To Support

So you also want to make it compatible with sleep, compatible with work that really gets down into the wits of optimization. But I think it's interesting to note that if you're going to

train at a regular time, you can take the days when you don't train and use that to enhance your cognitive focus for things that have nothing to do with exercise. So this might be writing, or reading, or music, or math, et cetera. Typically, I restrict these podcast episodes to about 90 minutes. So called ultradian cycle for learning. Today was a bit longer. And I admit that I tried to pack a lot into this. It is the last episode in this month on physical performance. I figured in this case more is better especially since everything is time-stamped for you. You certainly don't have to watch it all at once and you can come back to it over and over again into the precise locations in the episode that you like in order to take notes or extract the information that you need. I'd like to point you to Dr. Andy Galpin page. I highly recommend looking into the work that he's doing if you want more details. He's very, very skilled, excellent communicator. He's superb at what he does. He's a professor. He works with athletes. He works with typical folks in the exercise and muscle physiology world. Brad Schoenfeld's work. I also have a lot of respect for. I've never met him. I don't know him. There's no paid endorsement here. They're not sponsors are related to the podcast in any way. I just think the work is of very high quality and they're both on the academic side and the practical side. And of course there are other people out there doing fabulous work in this area as well. If you like this podcast and you're benefiting from the information that you're learning and you want to support us, the simplest and most straightforward way to do that is a zero cost way which is subscribe to the podcast on YouTube. Click the Subscribe button and to subscribe on Apple and Spotify as well. That really helps us. It helps us get the message about the podcasts out more broadly generally, and it ensures that you don't miss any episodes. We release episodes every Monday, but starting soon, and from time to time, we release shorter episodes in between. So you'll be sure to hear those episodes. In addition, check out the sponsors that we mentioned at the beginning of the podcast. If you like and if you're able to, supporting us through those sponsors is a terrific way to support our production staff and the podcast generally. A zero cost way to support the podcast is to tell your friends, tell your neighbors, tell anyone that you think might benefit from the information. The way this podcast is set up, the information is batched into four or five episodes, all centered around a given theme or topic like hormones, like sleep. So the episodes on sleep, for instance that were way back in January, and what seems like way back are still every bit as relevant today as they were back in January for somebody that has challenges with sleep and wants to understand sleep and get better at sleep or wants to understand their dreams or how to use sleep and dreaming to leverage

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