

## How To Build Endurance In Your Brain & Body | Huberman Lab Podcast #23

This episode I discuss endurance: our ability to perform effort over extended amounts of time. I describe the four kinds of endurance: muscular endurance, long duration (single-set) efforts, and the two kinds of high intensity interval training (HIIT). I discuss efficiency of effort and maximizing quality of effort, and a hydration formula. I review how our heart literally gets stronger when we oxygenate muscles properly. I also discuss motivation for long bouts of work and the visual physiological basis of the "extra gear" we all can leverage for effort. Finally, I review how accelerating as we fatigue can allow us to access untapped energetic resources.

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- 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 ROKA. ROKA makes sunglasses and eyeglasses. And I'm delighted that they're a partner and a sponsor for the podcast. As some of you may already know I've spent two decades or more studying the visual system, how we see? Vision is absolutely the most important sense by which humans navigate the world and survive. And our eyes as two pieces of our brain do many other important things as well. So taking good care of our eyesight is essential. Founded by two All-Americans swimmers from Stanford. ROKA was born out of an obsession for performance. They've carefully put science and purpose behind their design choices and they built absolutely terrific products as a result. The glasses are amazing. I love them because they look great. They are super comfortable and the optical clarity is incredible. They filter out sunlight in a way that still allows you to see contrast and shadows the way you need to. And for me, one of the things that's really irritating is if I have a pair of sunglasses that don't allow me to see all the things I want to see. And with ROKA glasses, I get incredible contrast but then I can also relax and be outdoors in bright light. And as the amount of light changes with cloud cover and things of that sort, my ability to see my surroundings coz it's still really sharp and really clear. And that only comes from really understanding how the visual system works, and how it adjusts to contrast and adaptation and all these different things. They really understand the science and that went into the design of these glasses. And as many of you know, sunlight and the viewing of light is also very important for setting circadian rhythm. So that's also been incorporated into the design and science behind these glasses. I do wear readers. I don't often wear them during the podcast, but I have to wear reading glasses at night. So I use their readers and I own a pair of their sunglasses. And I'm delighted with them. If you'd like to check out ROKA glasses, you can go to [www.roka.com](http://www.roka.com), that's R-O-K-A.com and enter the code Huberman to save 20% off your first order. That's R-O-K-A.com, enter the code Huberman at checkout to get 20% off your first order. Today's podcast is also brought to you by 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'm a big believer in getting regular blood work done for the simple reason that many of the important things that are vital to our immediate and long-term health can only be detected in a good quality blood test. The problem with blood tests is that most blood tests you get a lot of information back about that are too high or too low of this thing or the other thing. But making sense of that, and what to do with that information is very challenging. Even if you have a really attentive physician, oftentimes it's mysterious as to what to do with all this data. With InsideTracker, they make it very easy to understand what all the metabolic factors, hormone factors, et cetera, mean for you and what to do about those markers. So they offer you directives in terms of nutrition, supplementation, as well as lifestyle factors like exercise, sleep, et cetera, that can allow you to take control of those numbers and bring them into the ranges that are best for you and your long-term health. Another feature of InsideTracker that's great is their inner age test. This test shows you what your biological age and how it compares to your chronological age, which I can only imagine most everybody including me are extremely interested in how long am I likely to live? How old am I really in terms of my biology? If you'd like to try InsideTracker you can visit [www.insidetracker.com/huberman](http://www.insidetracker.com/huberman) to get 25% off any of InsideTracker's plans. Use the code Huberman at checkout.

Today's episode is also brought to us by Athletic Greens. Athletic Greens is an all-in-one vitamin, mineral, probiotic drink. I've been using Athletic Greens since 2012, and so I'm delighted that they're sponsoring the podcast. With athletic greens, you get a ton of factors that are good for you mixed into this one really good tasting drink. I like to mix mine with water and a little bit of lemon juice, and I drink that once or twice a day.

Typically, once early in the day, and sometimes also in the afternoon or even evening. I'm able to sleep after drinking in the evening just fine. The reason I been using Athletic Greens for so long that I continue to use Athletic Greens is that, one, I feel better when I take it. I just do. Psychologically, physically, I feel better. But also it covers all my bases of the things that I need for my general health. It's sort of a foundational supplement as I like to call it. In fact, when people ask me, what should I take? If I were to recommend just one supplement that people take it would be Athletic Greens. With Athletic Greens, you get support for your gut which is important, because the gut microbiome is important for the gut brain access, for mood, metabolism, hormones, et cetera. There are so many data that support that statement. As well, there are many factors in Athletic Greens that support general health metabolism, endocrine factors, immunity, et cetera. So with Athletic Greens, I drink it once or twice a day. And I know that I've got all that covered. If

you'd like to try Athletic Greens, you can go to [www.athleticgreens.com/huberman](http://www.athleticgreens.com/huberman). And if you do that, you can claim a special offer. They'll send you five free travel packs plus a year supplies, excuse me, of vitamin D3+K2. So you get the five free travel packs and a year supply of D3

#### 00:05:45 Why Everyone Should Train Endurance

if you go to [www.athleticgreens.com/huberman](http://www.athleticgreens.com/huberman) you can claim that special offer. For the last month four episodes to be exact, we've been discussing physical performance and skill learning. We've talked about how to learn skills faster, whether or not those are skills, athletic performance, dance, music, things of that sort. We've also talked about how to gain strength and how to lose fat faster by leveraging the nervous system. Things like shiver and non-shiver, non-exercise activity induced thermogenesis. We talked about how neurons can actually trigger accelerated fat loss. We talked about hypertrophy also called muscle growth and we covered everything from sets and reps protocols, how long to stay in a cold ice bath? When to get out? How to keep shivering? We've covered a lot of tools and a lot of science. So if you're interested in those things and you even perhaps want to learn a little bit about how we make energy ATP from carbohydrates or from fats, it's all covered in the previous four episodes. This was going to be the time that we moved to a new topic entirely, but we are going to do one more episode in this series on physical performance. For the simple reason that you asked many questions about something that's vitally important both for physical performance and long-term and short-term health and that's endurance. And so today we are going to talk about endurance. Now, if you're a strength athlete or you're not interested in endurance, don't depart just yet, because it turns out that there are ways to train endurance that are very different than I would have previously imagined. If you only think about long runs, long swims, marathons, half marathons, 10Ks, 5Ks and that sort of thing puts you to sleep kind of like Costello is snoring in the background right now. He's not a long distance endurance athlete, that's for sure. If you're interested in those things or if you are averse to those things, I encourage you to continue listening because we are going to talk about a little bit of science and then some specific protocols that really define what endurance is? The four types of endurance and ways to train those in concert with the other things that you might be doing like weight training or skill training or yoga. And if you are an endurance athlete, we are going to cover a lot of tools and

science that I'm certain will also help enhance your training and performance in races or even just recreationally. The topic of endurance I think has been badly misrepresented, frankly, online. And when you'd start digging into the science and you start talking to real experts in this area, what you discover, what I've discovered is that, it's an incredibly interesting area because it teaches us so much about how our body and our brain use fuels and how we can control which fuels are used by our body and brain? So today we will talk about the four kinds of endurance. We will also cover the topic of hydration which might sound incredibly boring. Like, okay, just drink more water. But it's really interesting because not only is hydration a limiting factor on performance, but there is a right way to hydrate, and there is a wrong way to hydrate. There actually is a formula that I'll teach you to know how much water to be drinking depending on your activity levels. And if that sounds like a simple thing, like, oh, just tap off water until your urine runs clear. That's actually the wrong advice. It turns out that if you don't hydrate properly, you can see 20 to 30% reductions in performance, whether or not that strength, whether that's increasing hypertrophy, whether or not that's running, swimming, even mental performance. So even if you're not an athlete or a recreational athlete at all, I encourage you to stay tuned for the part about hydration. So we're going to cover as usual a little bit of science and then we're going to dive right into protocols

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that you can apply if you like, and if you deem those correct and safe for you. Before we dive into all that, I want to make an important announcement, which has all the episodes of the Huberman Lab Podcast are now housed on a single website, which is [www.hubermanlab.com](http://www.hubermanlab.com). If you go to [www.hubermanlab.com](http://www.hubermanlab.com), you can find all the episodes in YouTube, Apple and Spotify format with links there. The website is also searchable. So if you go into the little search function which you'll find very easily, and you put in, for instance, creatine or sleep or ice bath or sauna, it will take you to the specific episodes that contain that information. And in addition, if you go to the website [www.hubermanlab.com](http://www.hubermanlab.com), you have the opportunity to sign up for what we call the Huberman Lab Neural Network. The Huberman Lab Neural Network is a zero cost resource where once a month perhaps more often you'll receive a email newsletter, and that newsletter will contain specific protocols, announcements, attachments of PDFs and things of that sort of protocols, tools and science from the podcast. We will also make

any announcements about live lectures which at some point I'll probably start doing in various cities in the US and probably around the world as well, as well as other things that I think would be really useful to you all of course at zero cost. So that's [www.hubermanlab.com](http://www.hubermanlab.com), sign up for the Neural Network newsletter. You can find that in the menu tab or it might pop up when you get there. And I hope you will join. And as a final announcement, if you're not already following us on Instagram, you can go to Huberman Lab on Instagram. And if you do that,

#### 00:11:28 How To Maintain Muscle

I often make announcements and release protocols and links to protocols and things there as well. I briefly want to touch on something from the previous episode which is that, if you are somebody that is trying to increase muscle strength and or size, or if you're simply somebody who doesn't want to increase muscle strength and size, and you just want to maintain the musculature that you have, it's vital that you perform at least five sets of resistance training per muscle per week. If we don't do that, we lose muscle over time. And that is one reason among many to have a regular resistance training protocol. Nobody wants to start resembling a folded over envelope or a melted candle. No one wants to have challenges getting up out of a chair or off the ground. Maintaining musculature is vital, not just to our immediate health, but to our long-term health trajectory. So I just want to emphasize that point. If you're curious about the sets, the reps, how close to failure to go or not go? Whether or not you should be doing your cardiovascular training before or after your weight training? All of that is in the previous episode right down to the details, and I like to think made simple for you to understand. But I do strongly believe that resistance training whether or not it's with body weight or bands or weights or simply lifting rocks in the yard or logs in the yard is vital for our systemic physiology and our overall health, and that includes our brain health.

#### 00:12:56 Endurance: It's Not What You Think, Crossover With Brain Function

And I described the reasons for that and the mechanisms in the previous episode. Today, I'd like to talk about endurance and how to build endurance, and how to use endurance for the health of your entire body. Endurance, as the name suggests is our ability to engage in continuous bouts of exercise, or continuous movement or continuous



effort of any kind. And I do believe that our ability to engage in activities that we call endurance training or physical endurance activities do have carry over to mental performance of things that require long-term effort. I'll touch on that at the end and why there's reason to believe that there is a biological crossover between those two things. I don't think it's simply the case that if you train yourself to be a strength and speed athlete and to do short bouts of exercise are very intense, that you can only do mental work that's of short bouts and very intense. But it is clear that cardiovascular exercise, exercise where you're getting your heart rate up continuously for a period of time, and endurance exercise we will define what that is in a moment, is vital for tapping into and enhancing various aspects of our biology in the body end in the brain such that our brain can perform work for longer periods of time, focused work, learning, et cetera. So I want to dive into the topic of endurance and I want to just begin by addressing something that's vital to any kind of effort, whether that's mental effort or physical effort.

00:14:38 Energy; Many Paths To ATP: Creatine, Glucose, Glycogen, Fat; Ketones

So as always a little bit of science and we'll get right into protocols. So the key thing to understand about energy production in the body, meaning your ability to think, your ability to talk, your ability to walk, your ability to run is this thing that we call ATP. ATP and mitochondria, which are just little what we call organelles within cells. These little factories that make energy, if you will. ATP is required for anything that requires energy, for anything that you do that requires effort. And there are different ways to get ATP. And we have been gifted as a species with the ability to convert lots of things into ATP. We can convert carbohydrates, literally the kinds of carbohydrates eat a bagel, you eat a piece of pizza. Pizza usually is dough, and it has cheese and some other things. Costello hears me talking about pizza. Costello loves pizza, by the way. Eating a piece of pizza, it gets converted into various things, fatty acids from the fats, glucose from the bread, and those things get converted into ATP within cells, through things like like glycolysis, things like lipolysis. I talked about this in previous episodes. So our muscles and our neurons use different fuel sources to generate ATP. The ones that are used first for short bouts of intense activity are things like phosphocreatine. If you've only heard about creatine as a supplement. Well, phosphocreatine actually exists on our muscles, and that's why people take creatine. You can load your muscles with more creatine. And though, and excuse me. Phosphocreatine is great for short, intense bouts of effort. So

when you're really pushing hard on something physical, let's say you see a car on the side of the road and that car is stalled and a person says, "Hey, can you help me push my car?" And you start to push. That's going to be phosphocreatine is going to be your main fuel source. Then you start to tap into things like glucose which is literally just carbohydrate is the sugar that's in your blood. And then if you keep pushing on that car, you keep engaging in a particular effort, or you keep studying or you keep listening to this podcast, you start to tap into other fuel sources like glycogen from your liver, which is just, it's like a little pack, just like you might have packed a sandwich or something for work. You have a little pack of glycogen in your liver that you can rely on. And you have fat stored in adipose tissue. Even if you have very, very low body fat percentage like you're one of these people as like 3% or 5% body fat really thin skin, very little body fat, you can extract lipids fatty acids from that body fat. It's like a storage pack, it is a storage pack for energy that can be converted to ATP. So without going into any more detail, when I say today energy or I say ATP, just remember that regardless of your diet, regardless of your nutritional plan, your body has the capacity to use creatine, glucose, glycogen, lipids. And if you're ketogenic, ketones. We'll talk about ketosis.

00:18:00 The Vital Need For Oxygen: But Why?

In order to generate fuel, energy. Now, the other crucial point is that, in order to complete that process of taking these fuels and converting them into energy, most of the time you need oxygen. You need air basically in your system. Now, it's not actual air. You need oxygen molecules in your system, comes in through your mouth and your nose, goes to your lungs and distributes via the bloodstream. Oxygen is not a fuel, but like a fire that has no oxygen you can't actually burn the logs, but when you blow a lot of oxygen onto a fire, basically, onto logs with a flame there, then basically it will take fire, it will burn. Okay? Oxygen allows you to burn fuel. So today we are going to ask the critical questions. What allows us to perform? What allows us to continue effort for long periods of time? And that effort could be a run,

00:19:00 What Allows Us To Endure (Anything)?

it could be a swim, it could be studying, it could be anything that extends over a long period of time. Well, you're going to need energy and you're going to need oxygen. But

the way to answer a question like what allows us to endure, right? Endurance. What allows us to keep going? Well, we think of things like willpower. But what's willpower? Willpower is neurons. It's neurons in our brain. We have this thing called the central governor which decides whether or not we should or could continue or whether or not we should stop, whether or not we should quit. Okay? So whether or not you're somebody who has a lot of what we would call resilience and endurance, or whether or not you're somebody who taps out early and quits early or can't handle frustration, that has to do with your fuel utilization and specific neurons. So we have to ask the question, what is the limiting factor on performance? Right? So instead of saying, what allows us to endure? We should say, what prevents us from enduring? What prevents us from moving forward? What are the factors that say, you know what? No more, I'm not going to continue this run. Or you know what? I've had a really long, hard day or maybe I've had an easy day or I'm feeling lazy, I just don't even really feel like getting up and moving. So what we're going to talk about today actually gets right down to the heart of motivation and fuel use. Motivation and fuel allocation. And we are going to talk about specific training protocols that you can follow that have carry over between the bodily systems of running swimming, et cetera, and the way that your brain works. So let's talk about endurance by asking first, what are the limiting factors on endurance? What stops us? Because in addressing that and answering that,

#### 00:20:46 The 5 Things That Allow Us To Persist/Endure & What Causes Quitting

we will understand what allows us to get into effort and to continue effort. There are five main categories of things that allow us to engage in effort. And they are neurons, nerves, muscle, muscle, blood, things in our blood, our heart and our lungs. Now, I don't want to completely write off things like the immune system and other systems of the body, but nerve muscle, blood, heart and lungs are the five that I want to focus on today, because that's where most of the data are. As we go forward into this, I want to acknowledge Dr. Andy Galpin, who as with the last episode, has been tremendously helpful and informative in terms of the exercise physiology. He's a true expert. He has a laboratory, he's a full professor who does work on muscle biopsy, who understands the science, but who also works with athletes and works with recreational athletes, professional athletes really understands at a variety of levels how all these systems work? He's the person I consulted with about today's episode, although I did access other literature as well. And

I'm going to mention a key review for any of you, aficionados, who really want to get down into the weeds. But I encourage you, if you want more detail to check out Dr. Andy Galpin's YouTube page, I think he's also on Twitter. He's definitely on Instagram. His content is excellent, and he really understands... I have learned and I really believe that an intellectual is somebody who understands a topic at multiple levels of specificity of detail and can communicate that. And Andy is a true intellectual of muscle physiology and performance. And if you hear the word intellectual and you kind of back up and cringe from that, understand that he's also a practitioner. So thank you, Andrew Galpin. Andy Galpin for your support in these episodes and we hope to have you as a guest on the podcast soon. So nerve muscle, blood, heart and lungs.

00:22:50 Why You Quit: It IS All In Your Mind

Let's talk about neurons and how they work. Okay? But I want to tell you about an experiment that's going to make it very clear why quitting is a mental thing not a physical thing. So why do we quit? Well, an experiment was done a couple years ago and was published in the journal Cell. Cell Press journal, excellent journal showing that there is a class of neurons in our brain stem, in the back of our brain that if they shut off, we quit. Now, these neurons release epinephrin. Epinephrin is adrenaline. And anytime we are engaged in effort of any kind, we are releasing epinephrin. Anytime we're awake really, we are releasing epinephrin into our brain. In fact, this little rroup of neurons in the back of our brain is called the locus coeruleus if you like. It's churning out epinephrin all the time, but if something stresses us out, it churns out more and then it acts as kind of an alertness signal for the whole brain. We also of course have adrenaline epinephrin released in our body which makes our body ready for things. So think about epinephrin as a readiness signal. And when we are engaged in effort, this readiness signal is being churned into our brain. When we relax and we're falling asleep, epinephrin levels are low. Okay, so they did a really interesting experiment where they had subjects engage in bouts of effort of trying to move forward toward a goal. But they manipulated the visual environment with the stripes, kind of like fences passing on both sides of them. And by doing that, they could trick subjects into thinking that their effort was either allowing them to move forward, right? Because these rungs on the fence were moving past, or that their effort was futile that they were no longer moving forward because they would make the runs move slowly even though the subjects were making a lot of effort to move

forward. Okay? So this is analogous or similar to being on a treadmill and you're trying to walk on this treadmill and you just can't move the conveyor, right? Or you're in virtual reality and you're putting a ton of effort, but it seems like you're moving excruciatingly slow. I had this experience recently in real life. I was doing a swim in the Pacific, I was trying to go south and I was swimming and I was caught in a current, not the current that pulls you out to ocean. And I kept looking to my left, and I saw this hotel on the shoreline, and then I was swimming and swimming and swimming and swimming, and 20 minutes later I looked to my left and the hotel is still exactly where it was before, which meant that I wasn't moving. It felt futile. Eventually, either the current changed or something changed and I eventually swam past the hotel, got back on the beach and eventually drove home. That's essentially what they did in this experiment. But what they found was these neurons that release epinephrin, there's another cell type called glia, which actually means glue in Latin, that is paying attention to how much epinephrin is being released. And at some point the system reaches a threshold. It reaches this threshold and it shuts off the release of more epinephrin. It's like I quit, that's it, no more effort signal. If they could extend the time before those glia said, ah, enough. If they could release more adrenaline into the system, then subjects would keep going. So our desire to continue or put differently, our willingness to continue and our desire to quit is mediated by events between our two ears. Now, that doesn't mean that the body's not involved, but it means that neurons are critically important. So we have two categories of neurons that are important. The ones in our head that tell us get up and go out and take that run. And the ones that allow us and encourage us to continue that run, and we have neurons that shut things off and say no more. And we of course have the neurons that connect to our muscles and control our muscles. But the reason we quit is rarely because our body quits, our mind quits. Now, we never want to encourage people to drive themselves to the point of injury, that's not going to be good for anybody, but it is good to know that it's neural. Our ability to persist is neural.

#### 00:27:19 The "90% Mental" Myth

So when people say is it, I hear that, you know, sports or effort or fighting, or it's 90% mental, 10% physical. That whole discussion about how much is mental, how much is physical? Is absolutely silly. It just proves that there's no knowledge of the underlying biology behind that statement. It's neither mental nor physical. Everything is physical,

everything is neurons. Your thinking is the responsibility of chemicals and electrical signals in your head. So it's not 90% mental, 10% physical. It's not 50/50. It's not 70/30, it's 100% nervous system. It's neurons. Okay? So when people say mental or physical, understand it's 100% neural. And I'd love for the, how much of it is mental and how much is physical to just disappear.

#### 00:28:10 The Critical Need For Carbohydrates & Electrolytes (& Sometimes Ketones)

That argument means nothing and it's not actionable. Now, what do nerves need in order to continue to fire? What do you need in order to get neurons to say, I will persist. Well, they need glucose. Unless you're on keto and ketogenic adapted, you need carbohydrate is glucose. That's what neurons run on. And you need electrolytes. Neurons have what's called a sodium potassium pump blah, blah, blah. They generate electricity. We could go into all this. I will probably do an entire lecture about the action potential, but basically in order to get nerve cells to fire, to contract muscle, to say, I'm going to continue. You need sufficient sodium, salt, because the action potential the actual firing of neurons is driven by sodium entering the cell, rushing into the cell. And then there's a removal of potassium. And then there's a kind of resetting of those levels by something called the sodium potassium pump. And the sodium potassium pump and sodium and action potentials, even if you don't know anything about that is ATP dependent. It requires energy. So you need energy in order to get neurons to fire. And it is pH dependent. It depends on the conditions or the environment within the brain being of a certain pH or acidity. pH is about how acid or how basic the environment is? And we will talk a little bit about pH in simple terms so you can understand. So nerves need salt, they need potassium. And it turns out they need magnesium and you need glucose and carbohydrates in order to power those neurons, unless you are running on ketones. And to run on ketones, you have to make sure that you're fully keto adapted. I will talk about adding in ketones on top of carbohydrate at the end of the episode. Okay, so that's how nerves work. You need carbohydrate, you need sodium, potassium and magnesium in order to drive the brain.

#### 00:30:10 Phospho-Creatine, Glycogen, pH, Temperature Is Key

Muscle. Muscle is going to engage in generating energy first by using this

phosphocreatine system. High bouts of effort really intense effort, short-lived seconds to minutes, but probably more like seconds is going to be this phosphate creating literally a fuel source in the muscle that you're going to burn, just like you would logs on a fire. And glycogen which is stored carbohydrate in the muscle, that also can be burned just like logs on a fire to generate energy. So let me make this crystal clear. If you move your wrist towards your shoulder and contract your bicep really hard, muscle fibers are burning up their own carbohydrate. They're converting that into ATP in order to generate that energy. Okay? And pH is important and temperature is important. In the episode on supercharge your physical performance, I talked all about how by using cooling specifically of the palms or the bottoms of the feet or the cheeks of the face using particular methods, you can adjust the temperature of the body and of muscle in a way that allows you to do more work, to do more reps, to run further, to keep going and to persist. And that's because if temperature is too low or too high, then ATP is not going to be available because of this whole thing called the pyruvate kinase pathway and the temperature dependence of pyruvate kinase. Check out that episode if you want to learn more about that. But temperature is important and pH is also important.

00:31:36 Using Your Blood, Heart, & Lungs To Go Longer, Further, With More Intensity

So we got nerve, muscle, and then there's stuff in our blood that's available as an energy source. And in blood, we got glucose. So literally blood sugar that's floating around. So let's say you have fasted for three days, your blood glucose is going to be very low. So that's not going to be a great fuel source, but you will start to liberate fats from your adipose tissue from your fat. Fatty acids will start to mobilize into the bloodstream and you can burn those for energy. And oxygen in your blood when you inhale, [inhales deeply] you're bringing oxygen into your blood. So these are all fuel sources in your neurons, in your muscle, in your blood, in your various tissues that are providing the opportunity to induce effort whether or not it's a run or swim or writing or talking. Now, there are some other factors that are important and those are the heart which is going to move blood. So the more that the heart can move blood and oxygen, well, the more fuel that's going to be available for you to engage in muscular effort and thinking effort. So your heart vitally important to your muscles ability to work and your brain's ability to work. And as I've mentioned, oxygen a few times, it should be obvious then that the lungs are very important. You need to bring oxygen in, and distribute it to all these

tissues, because oxygen is critical for the conversion of carbohydrates and the conversion of fats. And we could get into the discussion about whether or not oxygen is important for ketogenic metabolism, but you need oxygen there, you need to breathe and you need to breathe properly. So I just covered what would normally be about four lectures of energy consumption and energy utilization. I didn't go into much detail at all. But what I want you to imagine is that, you've got these different cell types. You've got neurons, you've got muscle, they need to collaborate in order to generate effort or to make the decision to do something or to think hard or to run hard or to run far. And then you've got fuel sources both in the neurons, in the muscle, in your blood, and then the heart and lungs are going to help distribute the oxygen and those fuels. And of course you have that little energy pack that we call the liver that will allow you to pull out a little more carbohydrate if you need it for work. Okay? So that's as much as I want to cover about energy consumption, because that's a lot. But what it tells you is that when you eat and you use food as a fuel source, that food can be broken down and you can immediately burn the glucose that's in your bloodstream, or you can rely on some of the stored fuel in your liver, or you can rely on stored fuel in the muscle, so-called glycogen. And there are a lot of different ways that we can generate ATP. So when we ask the question, what's limiting for performance? What is going to allow us to endure, to engage in effort and endure long bouts of effort or even moderately long bouts of effort? We need to ask which of those things, nerve, muscle, blood, heart and lungs is limiting? Or put differently, we ask, what should we be doing with our neurons? What should we be doing with our muscles? What should we be doing with our blood? What should we be doing with our heart and what should we be doing with our lungs that's going to allow us to build endurance for mental and physical work and to be able to go longer, further with more intensity? That's the real question? How can we do more work? And the way we do that is with energy, and the way to get energy to it, is to buy those five things. And so now we're going to talk about, how you can actually build different types of endurance? And what that does at the level of your blood, your heart, your muscles and your neurons. So we're going to skip back and forth between protocols, tools and the underlying science. So rather than heavy stack the science at the front end and then just give you all the tools at the end, we're going to talk about the protocols,

00:35:40 An Excellent Review on the Science of Training Adaptations (See Caption On YouTube)



the four kinds of endurance and how to achieve them? And we are going to talk about the underlying science as we move through that. If you would like a lot of detailed science, I encourage you to check out a review that we've linked in the show notes. And the review is called adaptations to endurance and strength training. This is a review article with many excellent citations. It's from Cold Spring Harbor Perspectives in Medicine. The Cold Spring Harbor Press is an excellent scientific press. Spent the last 21 years doing summers at Cold Spring Harbor teaching neuroscience, but Cold Spring Harbor is involved in all sorts of themes and topics related to neuroscience and medicine. This review by Hughes L. Ellefson. Ellefson that's the name. Ellefson and Barr, B-A-A-R. Adaptations through endurance and strength training is rich with citations. It can be downloaded as a complete PDF. There's no paywall and we will link to it. And it gets really deep into all the signaling cascades, the genetic changes within muscle with high intensity interval training, short-term, super high intensity training, weight training. So if you're a real nerd for this stuff and you want to get right down into how PGC-1alpha, P53 and PH20 change the adaptation features of muscle and gene regulation, that is definitely the review for you. If you're like most people, and you're not really interested in that level of detail, no reason to pick up the review, unless you just want to check out some of the figures and pictures. But I do want to offer that as a resource it's been in addition to discussions with Dr. Andy Galpin,

#### 00:37:15 The 4 Kinds of Endurance

it's been a primary resource for the content of this episode. So let's talk about the four kinds of endurance and how to achieve those? I do believe that everybody should have some sort of endurance practice, regular endurance practice. It's clear that it's vital for the functioning of the body and the mind. And there are clear longevity benefits. There are a lot of reasons why that's true, but the main one is that if we have good energy utilization in our musculature and in our blood, in our vascular system and in our oxygenating system, our lungs, the so-called cardiovascular system, respiratory system and musculature. The body and brain function much better. There are so many papers now, so much data to support that. So I do believe everyone should either try to maintain the muscle that they have, provided they've already gone through puberty and development. And they should be engaged in regular endurance exercise. Now, for

many people, they think endurance exercise. That means what? A hour long run or I got to get on the StairMaster or I have to treadmill for hours on end each week. And it turns out that's not the case. There are four kinds of endurance, and you can train specifically for any one of those, and you can vary your training. So let's talk about those four kinds of endurance. These are very interesting and they each have very different protocols that you use in order to build and maximize them.

00:38:53 Muscular Endurance: Powerful for Everyone: Posture, Performance, Resilience

And now you'll understand what fuel sources they use in order to build that thing we call endurance. So first of all, we have muscular endurance. Muscular endurance is the ability for our muscles to perform work over time, and our failure to continue to be able to perform that work is going to be due to muscular fatigue, not to cardiovascular fatigue. So not because we're breathing too hard or we can't get enough blood to the muscles or because we quit mentally, but because the muscles themselves give out. Okay? One good example of this would be, if you had to pick up a stone in the yard and that stone is not extremely heavy for you, and you needed to do that anywhere from 50 to a 100 times, and you were picking it up and putting it down and picking it up and putting it down and picking up and putting it down. At some point, your muscles will fatigue. They will fail to endure. Muscular endurance is incredibly useful for a variety of physical pursuits. And we will talk about the mental pursuits that it supports as well. In terms of physical pursuits, the ability for a given muscle to perform repeated work is going to improve your golf swing. It's going to improve your tennis swing. It's going to improve your posture, your ability to dance, your ability to repeatedly engage in an activity that requires effort in a way that's very different from the kind of endurance that you will build simply by increasing your cardiovascular fitness, your ability to generate kind of easy repetition. So let's talk about muscular endurance and what it is? Muscular endurance is going to be something that you can perform for anywhere from 12 to 25, or even up to 100 repetitions. And that's actually how if you like you would train muscular endurance. And I'll give the specific protocol in a few moments. So a good example is push-ups, right? If you were to get on the floor and start doing push-ups, even if you're somebody who has to do knees down push-ups, and you're doing your push-ups, eventually you won't be able to do any more push-ups and that's not going to be because you couldn't get enough oxygen into your system, or your heart wasn't pumping enough blood. It's

going to be because the muscles fail. That's why. So if you want to be able to do more push-ups or even more pull-ups. Muscular endurance is really what it's about. It's actually no coincidence that a lot of military bootcamp style training is not done with weights, it's done with things like push-ups, pull-ups, sit-ups and running. Because what they're really building is muscular endurance. The ability to perform work repeatedly over time for a given set of muscles and neurons. So what's a good protocol to build muscular endurance.

#### 00:41:50 Protocol For Building Muscular Endurance. No Major Eccentric Component

Let's just give that to you now and explain some of the underlying science as it follows. So a really good muscular endurance training protocol according to the scientific literature would be, three to five sets of anywhere from 12 to 100 repetitions. That's a huge range. Now, 12 to 25 repetitions is going to be more reasonable for most people. And the rest periods are going to be anywhere from 30 to 180 seconds of rest. So anywhere from half a minute to three minutes of rest. So this might be five sets of push-ups, done getting your maximum push-ups although for some people that might be zero and you have to do it knees down. For some people it might be 10 push-ups, for some people might be 25, but you could go all the way up to 100. Rest anywhere from 30 to 180 seconds, and then do your next set for a total of three to five sets. So it doesn't actually sound like a ton of work. The other thing you could do is something like a plank. A plank position is actually a way to build muscular endurance, not strength. Okay? I'm sure it could be used to develop strength, but it's really about muscular endurance. So you would do three to five sets of planks. Those planks would probably even because you're not doing repetitions, it's an isometric hold as we say, as kind of static hold or a wall sit would be another example. And you would do that probably for a minute or two minutes, take some rest of anywhere from 30, 60, or 180 seconds, and then repeat. So things like pushing a sled, push-ups, isometric planks, even pull-ups, those will all work. And as with others forms of training, you would want to do this, until you approach failure or actually fail and where you're unable to perform another repetition that would mark the end of a set. The one critical feature of building muscular endurance is that it has no major eccentric loading component. Now, I haven't talked much about eccentric and concentric loading. But concentric loading is when you are shortening the muscle typically or lifting a weight. And eccentric movements are when you are lengthening a

muscle typically or lowering a weight. So if you do a pull up and you get your chin over the bar or a chin up, that's the concentric portion of the effort, and then as you lower yourself, that's the eccentric portion. Eccentric portion of resistance training of any kind, whether or not it's for endurance or for strength is one of the major causes of soreness. Some people will be more susceptible to this, excuse me than others, but it does create more damage in muscle fibers. Muscular endurance and building muscular endurance should not include any movements that include major eccentric loads. So if you're going to do push-ups, it doesn't mean that you want to drop, you know, smash your chest into the floor. And by the way your chest should touch the ground on every push-up. That's a real push-up. Okay? It's not about breaking 90 with the elbows, it's about pushing down until your chest touch the floor and straightening out. That's a proper push-up. And a pull-up is where you pull up your chin above the bar. Neither of those should include a slow eccentric or lowering component. If you are using those to train muscular endurance the three to five sets of 12 to 25 and maybe even up to 100 repetitions with 3,280 seconds of rest in between. That means that jumping also is going to be a very poor tool for building muscular endurance, because jumping has a slowing down component as you land. So things like plyometrics or agility work where you're moving from side to side, and you're decelerating, you're slowing yourself down a lot, not going to be good for muscular endurance. Terrific for cardiovascular training and conditioning of other kinds and skill training and agility and all that. But if you want to build muscular endurance, you want to make your muscles able to do more work for longer. It's going to be this three to five sets of 12 to 100 reps, 30 to 180 seconds of mainly concentric movement. Okay? Not a slow lowering phase or a heavy lowering phase. So that might be kettlebell swings and things of that sort. Isometrics, as I mentioned, things like planks and wall sets will work. Now, what's interesting about this is that, it doesn't seem at all like what people normally think of as endurance. And yet it's been shown in nice, quality peer-reviewed studies, several of which are cited in the review I mentioned earlier, that muscular endurance can improve our ability to engage in long bouts of what we call long duration, low-intensity endurance work. So this can support long runs. It can support long swims. And it can build also... It can build postural strength and endurance simultaneously and that's mainly accomplished through isometrical. So things like planks are actually quite good for building endurance of the spinal erector muscles that provide posture of the abdominal muscles that are helpful for posture for being upright for the upper neck muscles and things of that sort. These days everyone seems to have texts

neck. Everyone is basically staring at their toes all the time as a default towards their toes. So isometric holds can be very good for building muscular endurance. You can spot people including yourself, perhaps with poor muscular endurance in the postural muscles because anytime they stop moving, they have to lean against a wall or their hip will move to one side, or they're always leaned to one side. I am guilty of this too. Some of you have actually pointed out. I like to think out of concern that I often am rubbing my lower back. And indeed I have some asymmetries of my postural muscles some of which are probably genetic and some of which are probably just from excessive work or something of that sort that have my right shoulder set lower than my left and things of that sort. If I wanted to improve those, I could improve those by really focusing on symmetry and isometric. Symmetry meaning holding my hands at equivalent positions in planks and doing isometric holds for building muscular endurance of the postural muscles. But this can also be done with, as I mentioned, kettlebell swings for the lower back and legs and posterior chain. So there are a number of different exercises you could do this with, but it should be compound exercises mainly. It's rare for people to do this kind of muscular endurance work specifically for things like bicep curls or triceps. And there aren't many activities that really rely on isolation of those muscles and repeatedly, right? It's hard... I'm sure there are some out there, but it's kind of hard to imagine. So you can do this with isometrics, you can do this with more standard non-isometric type movements,

00:48:40 How to Make Muscles More Resilient: Mitochondrial Respiration, Neuronal Firing

but make sure there isn't a strong eccentric load. So now let's talk about the science briefly of why this works? Well, that takes us back to this issue of fuel utilization and what fails? So if we would say, okay, let's say you do a plank and you're planking for, you know, maybe you're able to plank for a minute or two minutes or three minutes. At some point you will fail. You're not going to fail because the heart gives out. You're not going to fail because you can't get enough oxygen because you can breathe while you're doing that. You're going to fail because of local muscular failure. Which means that as you do, if you choose to do this protocol of three to five sets, et cetera, et cetera, to build muscular endurance, mainly what you are going to be building is you're going to be building the ability of your mitochondria to use oxygen to generate energy locally. And

that is something called mitochondrial respiration. Respiration because of the involvement of oxygen. And it's also going to be increasing the extent to which the neurons control the muscles and provide a stimulus for the muscles to contract. But this is independent of power and strength. Okay? So even though the low sets like three to five sets and the fact that you're doing repetitions and you're going to failure, even though it seems to resemble power and strength and hypertrophy type training, it is distinctly different. It's not going to generate strength, hypertrophy and power. It's going to mainly create this ability to endure to continually contract muscles or repeatedly contract muscles. Okay? Continually if you're using isometric holds, repeatedly, excuse me, if you're using repetition type exercise where there's a contraction and an extension the muscle essentially concentric and an eccentric portion. But remember that you want the eccentric portion to be light and relatively fast, not so fast that you injure yourself, but certainly not deliberately slowed down. It was recommended, I should say by Andy Galpin that you not use Olympic lifts for this, because once you get past eight or 12 or 25 repetitions, especially form on those Olympic lifts is key for not getting injured. And while some people can perform those sorts of lifts like snatches and deadlifts and cleans and jerks and overhead presses, probably not a great idea if the goal is to push the body to points of fatigue, because you do open yourself up to injury, unless you're very skilled at doing that, or you have a really good coach who can help you guide through those lifts. So that's one form of endurance which is muscular endurance. And it's mainly going to rely on neural energy. So nerves and muscle.

00:51:31 Long Duration Endurance: 12minutes or More, One "Set", Efficiency of Movement

And it's not going to rely quite so much on what's available in your blood, your heart or your lungs. So now let's talk about the other extreme of endurance which is long duration endurance. This is the type that people typically think about when they think about endurance. You're talking about a long run, a long swim, a long bike ride. Well, how long we'll anywhere from 12 minutes to several hours or maybe even an entire day, maybe eight or nine hours of hiking or running or biking. Some people are actually doing those kinds of really long events marathons, for instance. So anything longer than 12 minutes. And this type of work builds on fuel utilization in the muscles, it builds on the activity of neurons in the brain that are involved in what we call central pattern generators. We

talked about this in a previous episode or several previous episodes. These are groups of neurons that allow our body to engage in regular rhythmic effort without having to think about the movement too much. So running and stepping or swimming if you already know how to swim, or peddling on a bike or walking upstairs and hiking, you're not thinking about right, left, right, left. It's all carried out by central pattern generators. This is going to be at less than a hundred percent of your maximum oxygen uptake, your VO2 max, I'll talk about what VO2 max is. But I just want to give a sense of what the protocol is, and the underlying science. How many sets? One. Long duration effort is one set of 12 minutes or longer. So you're not counting repetitions. I sure hope that if you're going out on a 30 minute run or even a 15 minute run, that you're not counting steps, that you're not counting pedal strokes, that you're not on the rower counting poles on the rower. I suppose you could, but I think that would be pretty dreadful. Seems like a poor utilization of cognitive brain space. You're getting into regular repeated effort and your ability to continue that effort is going to be dependent mainly on the efficiency of the movement on your ability to strike a balance between the movement itself, the generation of the muscular movements that are required, and fuel utilization across the different sources of nerve muscle, blood, heart and lungs. So let's ask the question. Why would you fail on a long run? Why would you quit? Well, as you set out on that long run, assuming you have some glycogen in your liver and in your muscles, you're going to use that energy first, even if it's very low intensity. I guess we're not talking about sprinting, we're talking about heading out the door or starting off on a marathon. You're starting to assuming you have some conditioning or even if you don't, you're going to burn carbohydrate. You're going to burn glucose in the bloodstream, you're going to burn carbohydrate as those muscles contract. Those what we call slow twitch muscles. They're contracting, they start burning up fuel to make ATP to continue to contract. Your mind is going to use more or less energy depending on how much willpower, how much of a fight you have to get into with yourself in order to generate the effort. I really want to underscore this. If you're somebody that's thinking, maybe I go for the run, maybe I don't go for the run. I'll do it at two o'clock. Okay, 2:05. No, I only want to go on the half hour or maybe on the main hour. And you're going through all that. Guess what? You're burning up useful energy that you could use either for the run, for example, or for something else. When we think about something hard, when we ruminate, when we persevere on an idea or on a decision, we are burning neural energy and neural energy is glucose and epinephrin and all the things we talked about before. So willpower

in part is the ability to devote resources to things and part of that is making decisions to just either do it or not do it. I'm not of the just do it mindset. I think there's a right time and a place to train. But I also think that it is not good. In other words, it utilizes excessive resources to churn over decisions excessively, and you probably burn as much cognitive energy deciding about whether or not to do a given training or not as you do in the actual training. Okay? So we'll talk more about how this long duration effort can relate to mental performance, but the long duration effort should be one set, 12 minutes or longer. It could go for 30 minutes or 60 minutes or an hour. We'll talk about programming later in the episode. This is going to be less than a hundred percent of your maximum oxygen uptake. Your heart rate is not going to be through the ceiling or maxed out. But it's all about efficiency of movement. That's what you're building. When you go out for a run that's 30 minutes, you are building the capacity to repeat that performance. The next time, while being more efficient actually burning less fuel. And that might seem a little bit counterintuitive, but every time you do that run, what you're doing is you're building up mitochondrial density. It's not so much about mitochondrial oxidation and respiration. You're building up mitochondrial density. You're actually increasing the amount of ATP that you can create for a given amount of effort. You're becoming more efficient. Okay? You're burning less fuel overall doing the same thing. That's really what these long slow distance or long bouts of effort are really all about.

#### 00:57:00 Why Everyone Should Train Long Duration Endurance: Capillaries In Muscle & Brain

Now, why do this long duration effort? Why would you want to do it? Why is it good for you? Well, it does something very important which is that it builds the capillary beds within muscles. So let's talk a little bit about vasculature. We haven't done this too much yet, but if you have seen the episode on supercharging performance. We talked about these AVAs arteriovenous anastomosis where blood moves from arteries directly into veins, but that's unusual, that only takes place in the so-called glabrous skin of the palms, the face and the bottoms of the feet. Typically, for most all other areas of the body what happens is, arteries bring blood to a given tissue like a muscle, and veins return that blood back to the heart. There are exceptions, but in general. And in between arteries and veins are these little tiny what are called capillary beds or microcapillaries. So these are tiny little avenues, like little tiny streams and estuaries between the bigger



arteries and veins. Now, those are actually contained within muscle. And what's amazing is that you can increase the number of them. You can literally build new capillaries. You can create new little streams within your muscles and the type of long duration effort that I was talking about before to 12 minutes or more of steady effort is very useful for doing that, and is very useful for increasing the mitochondria, the energy producing elements of the cells, the actual muscle cells. And the reason is when blood arrives to muscles it has oxygen. The muscles are going to use some of that oxygen. And then some of the deoxygenated blood is going to be sent back to the heart and to the lungs. Now, the more capillaries that you build into those muscles, the more oxygen available to those muscles. I don't want to get too much into the physics of fluid flow. But basically it's the difference between taking a hose and sticking it into some dirt just directly like and turning on the faucet at a given rate, the spigot rather, or having a bunch of little hoses like a sprinkler system that go out and irrigate the whole yard. The irrigation is equivalent to this capillary bed system. And it's very good at using energy sources within blood. So the simple way to think about this is, when you go out for a run, let's say it's the first run you've done for a while, and you out for 12 or 15 minutes and somewhere right around 20 minutes you're like, that's it. I just can't continue. Well, when you come back the next time to do that run, you've built endurance largely because you've built these capillary beds. You've expanded these little streams in which blood can deliver oxygen to the muscles. And so it's going to feel relatively straightforward to either go a little bit quicker for the same duration, the same distance. Or to extend that run for another five to 10 minutes. So this long duration work, unlike muscular endurance like planks and everything that we were talking about before is really about building the capillary systems and the mitochondria, the energy utilization systems within the muscles themselves. And that's very important to understand. It's distinctly different than say building the neurons that fire the muscles. The neurons are already there, they're going to fire those muscles just fine. In fact, if your life depended on it, today you could probably run a marathon. You'd probably get injured, it would be very psychologically and physically painful. I don't recommend you do that unless you're trained for it. But if you were to train properly for it, if you were to do long duration bouts of effort once or twice a week or three times a week pretty soon it would become easy, because you're building these vascular micro beds or microvascular beds as they're called. Okay? So you're able to bring more energy to the muscles and they're able to utilize more energy.

## 01:01:00 Two Distinct Types of High-Intensity Interval Training: Anaerobic & Aerobic

So that's long duration. So we've got muscular endurance and we've got long duration endurance. And then there are two kinds in between that in recent years have gotten a lot of attention and excitement, but most people are not distinguishing between these two kinds of endurance. And that's a shame because in failing to distinguish between the two kinds of what we call high-intensity training, sometimes called high intensity interval training. Most people, perhaps you, are not getting nearly as much physical and mental benefit out of high intensity training as you could. So I want to talk about the two kinds of high-intensity interval training, and what each of them does for your brain and body, and what sorts of adaptations they cause? Because in doing that, you can really start to build up specific energy systems in your brain and body in ways that are best serve you for your cognitive work. And for other sorts of things like strength and speed or hypertrophy or for running marathons for that matter. So there are two kinds of high intensity training for endurance. Sometimes called high-intensity interval training. One, is anaerobic, so-called an aerobic endurance, so no oxygen. And the other is aerobic endurance.

## 01:02:20 Anaerobic HIIT: 3-12 Sets, Work:Rest Ratio of 3:1 or 1:3; Quality of Repetitions is Key

Both of which qualify as HIIT, high intensity interval training. So let's talk about anaerobic endurance first. Anaerobic endurance from a protocol perspective is going to be three to 12 sets. Okay? And these records and I'll talk about what the repetitions are, are going to be performed at whatever speed allows you to complete the work in good, safe form. Okay? So it could be fast, it could be slow as the work continues, your repetitions may slow down, or it may speed up. Chances are it's going to slow down. So what does this work? What are the sets look like? Remember long slow distance is one set. Muscular endurance is three to five sets. High-intensity anaerobic endurance is going to be somewhere between three and 12 sets. And it's going to have a ratio of work to rest of anywhere from three to one to one to five. Okay? So what would a three to one ratio set look like? Well, it's going to be 30 seconds of hard pedaling on the bike, for instance, or running or on the rower. These are just examples. It could be in the pool, swimming. It could be any number of things or air squats, or weighted squats if you will provided you can manage that. 30 seconds on, 10 seconds off. That's a very brief rest. So three to

one is just a good example would be 30 seconds on 10 seconds off. The opposite extreme on that ratio be one to five. So 20 seconds on a hundred seconds off. So you do the work for 20 seconds then you rest a hundred seconds. Now, what's the difference? What should you do three one ratio? So 30 seconds on 10 seconds off, or should you do one to five, 20 seconds on to 100 seconds off? Well, that will depend on whether or not the quality of the movement is important to you. So let's just take a look at the three to one ratio. So in the three to one ratio, if you're going to do 30 seconds of hard peddling on a bike followed by 10 seconds. So maybe one of these what they call assault bikes, and then you stop for 10 seconds and then repeat, chances are you will be able to do one, two, three, four, maybe even as many as 12 sets, if you're really in good condition that you'll be able to do all those because pedaling on the bike doesn't require a ton of skill. And if you do it incorrectly, if your elbow flares out a little bit or something, it's very unlikely that you'll get injured unless it's really extreme. Okay? But the same movement done for instance, with kettlebells. So 30 seconds on 10 seconds off. The first set will probably be in good form. The second one will be in pretty good form, but let's say you're getting to the fifth and sixth set and you're going 30 seconds on 10 seconds off chances are the quality of your repetitions will degrade significantly. And you increase the probability that you're going to get injured, or that you're going to damage in some way, or that you can't complete the movement or that some smaller muscles like your grip muscles might give out. Okay? So the quality of repetitions is going to drop considerably with the three to one approach. If you're just doing it for effort. And we'll talk about what this builds in your system in a moment, that's fine. But for most people, if quality of form is important, so maybe this is using weights, maybe you're doing squats. You're going to do 20 seconds on and 100 seconds of rest. Maybe it's even a barbell loaded squat, maybe you're doing kettlebells, maybe you've got some other resistance there that's allowing you to do this. What you'll find is that the longer rest, even though it's 20 seconds of intense effort, followed by a longer rest of about a hundred seconds will allow you to perform more quality repetitions safely over time. So what does building anaerobic endurance look like? And then I'll tell you what it's actually good for, in the true practical sense. What anaerobic endurance exercise generally looks like is that if you decide to do this for the first week, you might do this two or three times a week, maybe even just once a week, depending on the other things you're doing, we'll talk about programming at the end. And you would generate just three sets. So it might be three sets of 20 seconds of hard effort, followed by 100 seconds rest. Then you repeat 20

seconds of hard effort, 100 seconds rest, 20 seconds of effort, 100 seconds rest, and you might do that twice a week. And then each week you're adding one or two sets, okay? In doing that, you will build up what we call anaerobic endurance.

#### 01:07:00 Maximizing Oxygen Utilization, Heart Rate & Nerve-Muscle Energy Utilization

What is anaerobic endurance? Well, let's ask why we fail? Anaerobic endurance is going to be taking your system into greater than 100% of your VO<sub>2</sub> max. It's going to be taking your heart rate up very high and it's going to maximize your oxygen utilization systems. That is going to have effects that are going to lead to fatigue at some point in the workout. And that fatigue will trigger an adaptation. So let's ask what adaptation it's triggering. Well, it's triggering both mitochondrial respiration, the ability of your mitochondria to generate more energy by using more oxygen because you're bringing so... You're maxing out, literally you're getting above your VO<sub>2</sub> max. You're hitting that threshold of how much oxygen you can use in your system? One of the adaptations will be that your mitochondria will shift such that they can use more oxygen. And you're going to also increase the capillary beds, but not as much as you're going to be able to increase the amount of neuron engagement of muscle. So normally when we start to hit fatigue, when we're exhausted, when we're breathing really hard because the systems of the body are linked and we there's a component to this as well, a kind of motivational component. After that third or fourth or sixth set of, you know, 20 seconds on a hundred seconds off, or if you're at the other extreme 30 seconds on, and 10 seconds off. There's going to be a component of you want to stop. And by pushing through and repeating another set safely, of course. What you're doing is you're training the neurons to be able to access more energy, literally, convert that into ATP and for the muscles therefore to access more energy and ATP. And the adaptation is in the mitochondria's ability to use oxygen, and this has tremendous carry over effects for other types of exercise. So while I know and appreciate that people are using high intensity interval training of this kind or similar in order to just like burn fat, you know, do their workouts, quote unquote. It's very useful for building a capacity to engage in short bouts of effort repeatedly to really lock in. I don't want to use the word focus because it's not strictly mental focus, but to be able to generate short bouts of very intense work this can be beneficial in competitive sports or team sports where there's a sprinting component, where the field opens up and you need to dribble the ball down the field, for instance and shoot on goal. Or where you're

playing tennis, and it's a long rally. And then all of a sudden, somebody really starts, you know, putting you back on your heels and you have to really make the maximum amount of effort to run to the net and to get the ball across in that. Things of that sort. Okay? There are a variety of places where there's carry over from this type of training, but it does support endurance. It's about muscle endurance. It's about these muscles ability to generate a lot of force in the short-term, but repeatedly. Okay? So that's the way to conceptualize this. And it is different than maximum power. Even though it feels like maximum effort, it is not the same as building power and speed into muscles. Those are distinctly different protocols. So the key elements again are that you're bringing your breathing and your oxygen utilization way up above your max. It's not quite hitting failure, but you're really pushing the system to the point where you are not ready to do another set and yet you begin another set. You're not necessarily psychologically ready. I'll talk more about some of the adaptations that this causes in terms of stroke volume in a few minutes when we talk about how it is that work of this sort can increase our heart's ability to deliver blood and oxygen to our lungs and other tissues. I'm going to get very specific about how to breathe during these different types of protocols and what's happening at the level of the heart?

01:10:59 Aerobic HIIT; 1:1 Work:Rest Ratio, Tapping Into All Energy Utilization Systems

But I want to make sure I touch on the fourth protocol which is high intensity aerobic conditioning. So HIIT has these two forms, anaerobic and aerobic. And you just heard about anaerobic. High-intensity aerobic conditioning also involves about three to 12 sets. Starting off of course, with fewer sets as you're getting into this training and then extending into more sets as one parameter you could expand. Has again the same ratio of three to one. So 30 seconds on 10 seconds off, or one to five, 20 seconds on 100 seconds off, or a very powerful tool for building up aerobic conditioning is a one-to-one ratio. A one-to-one ratio is powerful for building on average. Most of the energy systems involving, remember we had these nerve muscle blood, heart and lungs. A one-to-one ratio might be you run a mile. And however long that takes, let's say it takes you six minutes or seven minutes, then you rest for an equivalent amount of time. Then you repeat. And then you rest for an equivalent amount of time. So you might run first mile is let's say seven minutes. Then you rest for seven minutes. Then you run a mile again, and it might take eight minutes and you rest for eight minutes. And you continue that for

a total of four miles of work. Four miles of running work, I should say. Or seven miles of work. You can build this up. Many people find that using this type of training allows them to do things like go run half marathons and marathons even though prior to the race date, they've never actually run a half marathon or marathon. Now, that might seem incredible. It's like how could it be that running a mile on, and then resting for running a mile and then resting for an equivalent amount of time, running a mile, resting for equivalent amount time for seven miles allows you to run continuously for 13 miles or for 26 miles. Well, I'm not discouraging people from ever doing the long duration endurance. I think that is very important. But it's because it builds up so many of these energy utilization systems. It really teaches you to engage, excuse me, the nerve to muscle firing. It improves ATP and mitochondrial function in muscle. It allows the blood to deliver more oxygen to the muscle and to your brain. And I'll explain how that is. And it allows your heart to deliver more oxygen overall. And it builds a tremendous lung capacity. And we will talk about exactly how to breathe and how to build lung capacity. Both for sake of warming up and for performance. So what would this look like? And when should you do this? Well, it's really a question for these workouts of asking how much work can one do in eight to 12 minutes, right? And then rest, and then repeat. How much work can you do for eight to 12 minutes then rest and then repeat? And how many times should you do this? Well, this is the sort of thing it's pretty intense. And so you would probably only want to do this two, maybe three times a week if you're not doing many other things. I will talk about how this program can be moved in with other forms of training. But I'll just give you a little hint now. It's very clear and it's described in the review article are referred to and we will link another article as well. That concurrent training, doing strength training and the endurance training of any of the four kinds that I'm describing today can be done. You can program those in the same week. But you want to get four and ideally six or even better 24 hours between these workouts. Because it is very hard, for instance, to do a one-to-one mile repeats like run a mile rest for equivalent time, run a mile rest for equivalent time to do that two or three times a week, and also do weight training before or do a long run afterwards. That would quickly lead to break down for most people, unless you have very, very good energy utilization systems. You're really kind of advanced or elite athlete, and or dare I say you're using tools to enhance your performance at the level of blood or hormones. And I'm actually going to talk about those at the end and why they work? So we have four kinds of endurance. Muscular endurance. We have long-duration endurance. We have high intensity interval training of

two kinds, anaerobic and aerobic. And this last type, the aerobic one works best.

01:15:20 Building A Stronger Heart & Better Brain: Eccentric Loading the Heart: Stroke Volume

It seems if you kind of do this one-to-one ratio. So how would you use these and what are they actually doing? Let's talk about the heart and the lungs and oxygen, because that's something that we can all benefit from understanding. And it will become very clear in that discussion why this type of training is very useful even for non-athletes in order to improve oxygenation and energy utilization of the brain and the heart. The brain and the heart are probably the two most important systems that you need to take care of in your life. Yes, your musculature needs to be maintained. If you want to build it, that's up to you. But you should try and maintain your musculature, but maintaining or enhancing a brain function and cardiovascular function. It's absolutely clear are key for health and longevity in the short and long-term. And the sorts of training I talked about today has been shown again and again and again to be very useful for enhancing the strength of the mind. Yes, I'll talk about that. As well as the health of the brain and the body. So let's talk about the sorts of adaptations that are happening in your brain and body that are so beneficial in these different forms of training. If you are breathing hard and your heart is beating hard. So this would be certainly in the high intensity anaerobic and aerobic conditioning. 'Cause you're getting up near your VO2 max in high intensity aerobic conditioning, and you're exceeding your VO2 max in high intensity anaerobic conditioning. What's going to happen is as of course, your heart beats faster, your blood is going to be circulating faster in principle. Oxygen utilization in muscles is going to go up and over time, not long, very quickly what will happen when those capillary beds start to expand? We talked about that. But in addition, because of the amount of blood that's being returned to the heart, when you engage in these really intense bouts of effort repeatedly, the amount of blood being returned to the heart actually causes an east centric loading of one of the muscular walls of the heart. So your heart is muscle. It's cardiac muscle. We have skeletal muscle attached to our bones and we have cardiac muscle, which is our heart. When more blood is being returned to the heart because of the additional work that your muscles and nerves are doing, it actually has the effect of creating an east centric loading, a kind of pushing of the wall, the left wall. I realize I'm not using the strict anatomy here, but I don't want to get into all the features of the

structural features of the heart. But the left ventricle essentially getting slammed back and then having to push back in a kind of east centric loading of the cardiac muscle and the muscle thickens, but not because the heart thickens overall, it's actually a strengthening of the cardiac muscle in a way that increases what we call stroke volume. Meaning as more blood is returned to the heart. There's an adaptation where the heart muscle actually gets stronger and therefore can pump more blood per stroke per beat. And as it does that, it delivers because blood contains glucose and oxygen and other things. It delivers more fuel to your muscles which allows you to do yet more work per unit time. Okay? So when we hear that, oh, you know, so-and-so has a or maybe you have a nice low heart rate that maybe you're one of these really extreme folks like 30 or 40 beats per minute, although most people are sitting at 50, 60, 70, 80, that's your resting heart rate. If you exercise regularly and you do long duration aerobic work, your heart rate will start to go down, your resting heart rate. It will increase the stroke volume of your heart. If you do this high intensity type training where your heart is beating very hard. So maybe the one-to-one ratio mile run repeats that I described a minute ago. Let's say you do that twice a week for three or four. And I said, it could go all the way up to 12 rep sets, which is a lot. I don't recommend people start there. Pretty soon, the stroke volume of your heart will really increase. And as a consequence, you can deliver more fuel to your muscles and to your brain, and you will notice that you can do more work meaning you can do the same work you were doing a few days or weeks ago with relative ease. Your cognitive functioning will improve. This has been shown again and again, because there's an increase in vasculature. Literally, capillary beds within the brain, the hippocampus areas that support memory, but also areas of the brain that support respiration, that support focus, that support effort. This isn't often discussed, but the ability to deliver more blood and therefore more glucose,

01:20:10 Resistance & Weight Training: Useless for the Brain? What Is Good For the Brain?

remember neurons run on glucose and oxygen to the brain is a big feature of why exercise of the kind of describing helps with brain function. Now, weight training does have some positive effects on brain function also. When I say weight training, I'm really... I should be more specific. I really am referring to strength and hypertrophy training. Strength and hypertrophy training especially if it's of the sort where you get into the burn



as we talked about last episode and you start generating lactate as a hormonal signal that can benefit your brain, et cetera. It can have positive effects on the brain. And frankly, there haven't been as many studies of resistance training strength and hypertrophy training on brain function, mainly because most of those experiments are done in mice or primates, non-human primates, I should say. And it's hard to get mice to do resistance training. Okay? It's hard to get humans to do resistance training. It's definitely hard to get mice to do resistance training. There are ways to do it, but it's hard to get them to do say, you know, three sets of eight on the deadlift and then do some curls and then do some chin-ups and this kind of thing. Okay? It's pretty easy to get a mouse to run on a treadmill and you can set the tension on that treadmill to make it so that it's easier or harder for the mouse to turn that wheel. So that's one of the reasons. However, it's very clear and you should now understand intuitively why the kind of standard strength and hypertrophy type workouts are not going to activate the blood oxygenation and the stroke volume increases for the heart that the sorts of training I'm talking about today will. It just doesn't have the same positive effects. Now, that isn't to say that if you just weight train that you'll be dumb or that you'll lose your memory over time, you might, but it is to say that endurance work in particular the high intensity and long duration work that I've talked about today. The two high intensity protocols and the long duration work has been shown again and again and again, to have positive effects on brain function. Not through the addition of new neurons, sorry to break it to you, but that's not a major event in the exercised or non-exercised human brain, for reasons we can talk about in a future episode. But it still has many positive effects through the delivery of things like IGF-1, but also just through plain oxygenation of the brain and the way it promotes the development of microvasculature to develop, to excuse me, to deliver new neurons more nutrients. If neurons don't get oxygen and glucose, they do die. Unless there's another fuel source like ketones which can replace the glucose. If you don't give oxygen to neurons, if you don't deliver enough to them, you get what's called ischemia, you get little micro strokes. So the type of exercise I'm talking about today in generating intense heart rate increases provided that safe for you to do. Breathing hard, that's going to deliver oxygen in blood, increase stroke volume of the heart and is going to improve brain function has been supported by many, many quality peer-reviewed studies. So that's one form of positive adaptation. I also talked about just sort of performance adaptations. How doing high intensity aerobic conditioning of the mile repeats type training can actually improve your ability to do long bouts of intense work.

## 01:23:25 The Strength-Endurance Tradeoff; How Long to Wait Between Workouts

It also seems like it dovetails or is compatible with resistance training that's aimed towards strength and hypertrophy. Now, in full disclosure the data seemed to indicate that if people just weight train or train for strength, so three reps, rest five minutes, three reps of heavyweights, et cetera. Yeah, you'll get much stronger than you would if you're doing things like five repetitions up to 12, or 12 to 25 reps and you're going out for long jogs. There's always going to be a compromise in adaptations, unfortunately. It does seem like you can do concurrent training as I mentioned before, if you allow anywhere from four to six or ideally 24 hours between workouts. As I mentioned in the previous episode, if you want to know if you are recovered from a workout? A great way to do that is to apply the carbon dioxide tolerance test, which is four breaths in and out, inhale, exhale, inhale, exhale, inhale, exhale, inhale, exhale, then a big inhale and then a slow controlled exhale. If that slow controlled exhale is 60 seconds or longer, it means that your parasympathetic, your calming nervous system is under your control. And it's likely, I should say likely that systemically your whole nervous system has recovered from whatever it is that you've been doing and experiencing in life including work in relationships. If not, you might want to take a rest day, dare I say. Or Costello's on is what? He's 10 now. I think he's on his 12,000 thrust day. Most people need I should say, one to two full rest days per week. I know there are people going to say that's ridiculous and okay, maybe you have amazing recovery abilities, also depends on training intensity. Many people benefit from having one or two full rest days per week. At least one, some people don't need to. But if you are not able to extend that exhale on the carbon dioxide tolerance test past 60 seconds or so, 45 seconds, 60 seconds chances are, your so-called sympathetic nervous system, your stress system is chronically elevated and you're not really putting the brake on that system enough. And that's a subconscious thing. There are ways that you can accelerate recovery, but I would encourage you to listen to the previous episode. It's time-stamped for how to assess recovery. So how often to program these things will depend on the other things you're doing. I think it's perfectly reasonable to do this type of training with other types of training.

## 01:25:45 Breathing During Endurance, Explosive and Weight Training: Nose, Mouth,

## Gears

And I'll talk about a variety of combinations of those toward the end of the episode. I do want to talk about how to deliver more energy and oxygen. These are tools that are extremely useful, I believe and that are grounded in physiology. That three things I'd like to talk about, are how to breathe? What to do immediately after training and hydration? And I promise I will get back into programming and sort of protocols, but these are vitally important to your ability to perform endurance work in particular. And they are grounded in how neurons and blood and oxygen and your heart work together. So let's first talk about breathing or respiration. We breathe a couple of different ways, but let's just remind ourselves why we breathe? We breathe to bring oxygen into our system, and we breathe to get rid of carbon dioxide. And we need both oxygen and carbon dioxide in order to utilize fuel and for our brain and body to work. It's not the oxygen is good and carbon oxide is bad. They have to be present in the appropriate ratios. So one thing that is very clear is our ability to deliver oxygen to working muscles enter our brain is going to be important for our ability to generate muscular effort especially of a kind of what I was talking about today, but also weight training and other forms of skill-based effort, et cetera. And our ability to think. If you're holding your breath for too long, if you're breathing too much, if you're what they call over-breathing or under breathing, if you're shallow breathing, if you're mouth breathing, these are all things that can really impede mental and physical performance. So let's make it really simple and then I promise to do a future episode all about recipes. There are two main sources of air for your body and it's air coming in through your nose and air coming in through your mouth. In general nasal breathing is better. It scrubs the air of bacteria and viruses. You have a microbiome in your nose that benefits. There are a number of reasons, it's also just a more efficient system believe it or not, even though it feels like you can gulp more air with your mouth. Getting good at nasal breathing is useful. A gear - System of the type that Brian McKenzie and colleagues have developed, I think is a good way to conceptualize this. If you're doing long duration work, try and do it all nasal breathing. If you have deviated septum, it's probably cause you don't nasal breathe enough. Mouth breathing is something that many people suffer from. You are more prone to infections. It's not as efficient, et cetera. There is a place for mouth breathing. However, it's usually, if you need to do a strong exhale, oftentimes you can discard more volume through the mouth, unless you're very trained at nasal breathing. So if you're doing high intensity

training, a good way to conceptualize this is to exhale on the max effort, and then to inhale on the less intense part. So that might be as you're generating the movement, you know, you're in the concentric part of the movement you exhale, right? Just like on a bat swing or something like that, or fighters and martial artists do this differently depending on how they were trained and their different purposes, but they kind of like huh or ssh, they kind of exhaling during the effort and then inhaling on the portion of the repetition that is not the highest effort portion. Usually that's the eccentric phase of anything involving or rowing and things of that sort. So nasal breathing is great, but as you increase the intensity of your endurance work, you will need to incorporate the mouth. So a gear system would look something like first gear would be just nasal breathing or second gear would also be just nasal breathing. But with more effort, third gear again, power speed endurance has a lot more about this. You can go to their website. I think it's a very intelligent way to conceptualize this. As you go into more max effort, then you're going to third and fourth and fifth gear. And at some point you're not thinking about nose or mouth. You're just trying to hang on for dear life and complete the work safely. And that means breathe through whatever orifice works for you. So that's one aspect, nose versus mouth.

#### 01:29:50 Intercostals & Diaphragmatic Breathing: Warming Up Intercostals Is Useful

The other aspect is whether or not you're using your ribs, the intercostal muscles are these muscles that the Bruce Lee had these remarkable intercostal muscles that allow you to lift the rib cage or the diaphragm which is a skeletal muscle that sits below the lungs. Just to remind you, when you inhale, the diaphragm moves down, when you exhale, the diaphragm moves up. Okay? Here's something that most people don't do and would benefit tremendously from. And I can say this because Andy Galpin's lab has done work on this exploring how warming up the intercostals and the nerve to diaphragm pathways before any kind of endurance work or in the first few minutes of endurance work can allow you to breathe more deeply and to deliver more oxygen to the blood, [burps] excuse me, and to the muscles and to be able to do more work more efficiently. So what that involves is sometimes sitting, sometimes standing and just really concentrating on two things. We always hear about how we should diaphragmatic breathe. And that means that our belly moves out when we inhale. So [inhales deeply] our stomach expands, but also expanding the intercostals which means actually raising

the ribs, chest breathing.

#### 01:31:00 Increasing Motivation & Adrenaline

We're all told that in yoga class don't breathe with your chest this, [inhales deeply]. But actually that is warming up the intercostal muscles. So this is also a great way to generate adrenaline if you do it a little bit intensely. So let's say you're feeling unmotivated to train, I don't particularly like doing endurance training until I'm actually doing it. So I use and benefit from having a practice where I'll just sit there and for about three minutes I'll just breathe very deeply trying to raise my chest as much as I can for maybe a minute, and then contracting my diaphragm and expanding my stomach outward when I inhale. By the end of that you're actually delivering more oxygen to your system. My lab has looked at this in a totally different context. Andy's lab has looked at it in the context of physical performance. So warming up the breathing muscles should make sense, given that you now know that muscles and neurons need glucose and they need oxygen in order to function. And so that's a great warmup. You can also do this while walking or while getting on the bike and starting to peddle, really starting to think about warming up the breathing system. And then you can decide if you want to do pure nasal

#### 01:32:10 Eliminating the "Side Cramp" With Physiological Sighs

or a combination of nasal and mouth breathing and so on. So that's something that we don't often hear about. The other one. The other tool, rather that I talked about in a previous episode, I'll just mention again, is some people when they do endurance type work they get a stitch in their side. They feel like they've got a side cramp. Very rarely is it actually a skeletal muscular cramp, it's oftentimes it's a referenced pain of the phrenic nerve that innervates the liver. So the phrenic nerve is responsible for the movement of the diaphragm. It is a very important system, but it has a number of what we call collateral. So it branches to other organs. Runs over other organs. Sometimes when we're breathing shallow and we are in physical motion and we're engaging in physical effort, we'll feel that side stitch. And we think, oh, I've got a cramp or maybe I'm dehydrated or maybe I need to run with my hands over my head, excuse me. Typically, you can relieve that side cramp, which isn't a cramp at all. That side stitch by doing the

double inhale, exhale, really breathing deeply. [inhales deeply] And then sneaking a little bit more air in. That's a double kind of firing or what we call volume of action potential sent from the phrenic nerve to the diaphragm, which will also activate that collateral, that branch literally of the nerve that innervates the liver. And then when you exhale, you offload a bunch of carbon dioxide, but if you repeat that a few times often, in fact, for me every time but often what'll happen is that side stitch will just naturally disappear. Just means you're not breathing properly. You're the phrenic nerve is firing in a way that's kind of aggravating that referenced pain. There's nothing kind of voodoo or mysterious about this. It just has to do with the way that the different nerves travel in the body. So as you set out on your run or maybe you're going to do some muscular endurance work or high intensity work, warming up the intercostals, warming up the diaphragm is good. And there are exercises and there is work that you can do to strengthen the intercostals and to strengthen the diaphragm during bouts of this kind of effort. And I would say that one of the ways that you can do that best is by really focusing on getting the maximum diaphragmatic expansion and chest lifting. What we're all told now not to do, you know, don't chest breathe, belly breathe. The intercostals are there for a reason and they are perfectly good at filling your lungs. And they work best when they collaborate with your diaphragm. But when you are starting to fatigue to start to really inhale deeply and try and really expand those to deliver more oxygen to your system. While we're talking about delivering more oxygen

01:34:45 Accelerating Through "The Wall": Accessing Alternative Fuel Sources; Ketone Use

to your system, I want to share with you a useful tool that will now make total sense mechanistically why it works, which is oftentimes when we are on a long run or in long duration bouts of effort. We will hit the so-called wall, right? We will bonk. I think they used to call it, do they still call it that Costello? He's asleep. We bonk. Where we just we think no, we can't continue. It's a curious thing as to whether or not that's neural or whether or not it's fuel-based, there's certainly going to be a psychological or motivational component. But one way that you can reveal this kind of extra gear, the capacity to push on is by understanding the way that different muscle fibers use energy differently. Remember the fast-twitch phosphocreatine system and the slow twitch system that relies mainly on lipids and glucose. Okay, well, even if you don't remember

all that, if you've been running steadily for a long time and you're starting to fatigue and you feel like it's time to quit. You may have not tapped into an alternative fuel source. One thing that you can do is you can actually increase your speed. This is also true of work where you're doing repetitions with kettlebells or something. You can start to increase your speed. So run faster, pedal faster, row faster, swim faster not all out sprint. But in doing that, you're shifting the the muscles and the nerves over towards utilizing a separate fuel source or a distinct fuel source. Maybe the phosphocreatine system if it's a quick about of intense acceleration, or maybe it's a combination of lipids and carbohydrates in your system that weren't available to you prior. Now, of course, if you completely deplete your liver glycogen, you completely deplete everything, you're only going to be running on stored fuel and fats and eventually you'll start metabolizing protein, muscles themselves. But this is a kind of a unique way to realize that, oh, you weren't out of energy at all, you're just over-relying on one fuel source. And this is the reason why, especially elite athletes are starting to both rely on carbohydrates. So they're doing the whole carb depletion then carb loading thing. They're loading up their liver and their muscles with plenty of glycogen by eating pastas and rice and stuff before races. But they are also ingesting ketones during races, during long bouts of effort, because ketones can be a quick form of energy. There's no reason why you can't use ketones if they are taking exogenous ketones and carbohydrate. And in combination, remember the body is accustomed to using multiple fuel sources, fatty acids, carbohydrates all these things. It's only in the, you know, of internet age that we think in terms of, oh, well you're either keto or you're burning sugar, or you're fat adapted or key or fat fasting or fast fasting or fat fattening. Costello woke up when I said fat fattening. I'm not talking about you Costello. So the point is that your body is used to using multiple fuel sources. So if you're kind of hitting that wall, sometimes accelerating can actually allow you to tap into a new fuel source or combination of fuel sources just based on the way that muscles use fuel. So that's another tool.

01:37:50 Hydration: Why Hydrate, How To Hydrate, & How Much Fluid To Drink

The other thing that's really important to think about in terms of endurance type work is hydration. And I think hydration is important for all forms of physical work and exercise not just endurance. The deal with hydration is that we've been taught about hydration all wrong. But let's remember what neurons work on? What do they use in order to fire?

Well, they certainly need water, right? We need water in our system, I should say. But remember they use electrolytes, sodium and potassium to generate those action potentials to actually get neurons to contract, to be able, excuse me, muscles to contract and for our brain to function and to be able to think. Typically, we're going to lose anywhere from one to five pounds of water per hour of exercise. And that's going to vary tremendously, it's going to vary on weather, it's going to vary on intensity, probably more like five pounds, if it's hot day and you're exercising very intensely. So about one to five pounds per hour. Now, you know how much you weigh. So if you think about your weight in pounds, once you lose about one to 4% of your body weight in water, you're going to experience about a 20 to 30% reduction in work capacity. In your ability to generate effort of any kind, strength, endurance, et cetera. You are also going to experience a significant drop in your ability to think and perform mental operations. So hydration is key. Now, many people have been told, well, if you urinate and your urine is clear, well, then you're hydrated enough. Sometimes that's true. Sometimes that's not true. Also and this isn't a topic I enjoyed discussing, but a urine is a biological phenomenon. It's actually filtered blood every once in a while and if there's a kid and it's a family friend, I'll say, "Did you know that your pee "is actually filtered blood?" And they usually kind of go wide-eyed. But then they go, "Oh, that's kind of cool." Like kids have this natural curiosity about blood and pee and stuff. That's not contaminated by our preconceived notions of those things being gross, because you're in being filtered blood can give you some indication as to whether or not you're hydrated enough or not. And in order to really assess that, it's not going to be sufficient to urinate into another volume of water and assess whether or not your urine is very dark or very light. It actually requires urinating into a small volume and saying, well, is it darker or lighter than before? It's not something you really want to do most places. The etiquette of most gyms and environments is not suitable for that. But one of the things that you can just do is you configure, well, I'm going to lose one to five pounds of water per hour. You can show up to exercise reasonably hydrated with electrolytes. So potassium, sodium and magnesium are really key. Yes, it's true, you can die from drinking too much water in particular because it forces you, if you drink too much water, you excrete too many electrolytes and your brain will shut off. You'll actually your heart will stop functioning properly. So you don't want to over consume to the extreme either, but there are a number of equations that go into figuring out how much water you need based on how intense your training, et cetera, body size, et cetera. Just remember you burn, you lose, excuse me about one to five



pounds of water per hour, depending on how hot it is, and how intensely you're exercising. Once your body weight drops by one to 4%. So you can just figure, well, if you lose five pounds per hour, you exercise for two hours. Let's say you're about 200 pounds, that's about 10%. Okay? Well, you want to replace that before you very quickly or not. You want to replace that all along before you start experiencing

01:41:35 "The Galpin Equation"; Gastric Emptying Time, Adapting Hydration Mid-Training

this massive 20 to 30% reduction in work capacity of muscles and the brain. A simple formula. What I call it, the Galpin equation. Hereafter, referred to as the Galpin equation is a formula that gets you close to the exact amount that you would want that Dr. Andy Galpin came up with, which is your body weight in pounds divided by the number 30. And that is how many ounces you should drink for every 15 minutes of exercise. So once again, the Galpin equation. Your body weight in pounds divided by 30. That's the amount of fluid to drink in ounces, right? Every 15 minutes of exercise. Now, if you are sweating a lot, you may need more. Okay? If you're already very well hydrated, you may need less, but that's a good rule of thumb to begin and to start to understand the relationship between hydration and performance. There is a phenomenon in which gastric emptying, the ability to move stuff out of your gut, including water and electrolytes out of your gut and into the bloodstream and for delivery to the tissues of your body for effort is hindered when you get above 70% of your VO<sub>2</sub> max. In other words when you're doing high intensity training sometimes people experience that ingesting water during intense training is difficult. It is something that can be actually trained up. It's a matter of learning to kind of relax your abdominal muscles. And there's some other aspects of adaptation that will allow you to drink during higher intensity work. As Galpin says, don't try and ingest fluids when you're working out or competing at higher than 70% of VO<sub>2</sub> max if you've never done it before. You want to train up this capacity. People can learn how to consume fluids during a race or consume fluids during bouts of exercise that are very intense. And a lot of people don't want to do that, 'cause they don't want to have to stop to urinate, et cetera. But given the crucial role of hydration for muscular performance and for brain performance, it seems that if you're going to be doing a lot of high intensity interval training of the various concepts talked about today or high intensity training of any kind that hydration is key and learning or in other words, getting your

system to adapt to ingesting fluids in the middle of these workouts is something that seems beneficial. At least to me, in terms of the trade off between being dehydrated and the somewhat discomfort of maybe drinking some fluids. So you sip small amounts of fluid initially and then you're able to take bigger and bigger gulps as time goes on. And pretty soon you're able to drink mid-set or be, excuse me, not mid-set. Please don't do that between sets and your workout

#### 01:44:20 Boosting Mitochondrial Density With Cold; Wait 6 Hours Before Cold/Between Training

or while you're still breathing hard after a mile repeat or something of that sort without much disruption or any at all to your performance. Last episode we talked about how to assess recovery and things that you might want to do to improve recovery, how exposure to ice baths and cold showers can reduce inflammation which can be great for recovery, but can inhibit some of the adaptations for strength and hypertrophy. Because inflammation isn't good or bad. Inflammation isn't like a nice person or a mean person. It's both. It's a great thing for stimulating adaptations, but you don't want it around too long. And so we suggested that you not do ice baths within probably six hours of any training where the goal was hypertrophy or strength training. There is some evidence that getting yourself into an ice bath or cold shower after endurance training can actually improve the mitochondrial aspects of endurance exercise that you can get improvements in mitochondrial density, and you can get improvements in mitochondrial respiration by doing that afterwards and that it can facilitate recovery. That's still a bit of a controversial area. I do think that what I mentioned earlier that waiting at least six hours and probably more like 24 hours between workouts is a good idea. That getting at least one full day of rest each week, for some people that'll be two. I have to say I'm one of these people that after two days of absolutely no exercise, I do perform better consistently across all aspects of physical performance and mentally I feel better as well even though I load to take those days off unless I'm really exhausted it does seem to help my training. Some people can train seven days a week and they're fine.

#### 01:46:00 Accelerating Recovery with 5 Minute Parasympathetic Down-Shift After Training

I think it just is there's a lot of individual variation. You want to work on sleep and maximizing sleep for recovery nutrition, of course, as well. I talked about sleep in the first four episodes of the podcast. If you have trouble with sleep definitely check out those episodes. It's very clear and a number of sports teams even some folks that I work with, and Andy Galpin and others are starting to incorporate a what's called a parasympathetic down-regulation after training of any kind as a way to accelerate recovery and enable you to do more work. In other words, get back to work out sooner. What is parasympathetic downregulation? It means finishing your training and instead of just hopping on the phone or hopping into your car and heading off to take five minutes minimum, maybe ideally more like 10 or 20, but for sake of time five minutes minimum and doing just some slow pure nasal long exhale breathing or lying down and just kind of zoning out. That it seems can accelerate recovery and allow you to get back into other types of work, mental work or physical work more quickly which makes total sense because remember your nervous system and recovery and work is a local phenomenon which muscles were you using. You know, were you using your glutes, your hams and your back or were using your shoulders, et cetera. But it's also a systemic thing. It's also about those neurons in the locus coeruleus that are releasing epinephrine and you want to quiet all that down after training. You want to really just zone out. Think Costello, channel your inner Costello, and just mellow out for five to 20 minutes and then move into the rest of your day. Five minutes should be manageable. Even if it's just sitting in the car with your eyes closed doing that downregulation breathing. I think you'll see big benefits in terms of allowing yourself to come back sooner, do more work over time and just perform and feel better generally, as well as be able to think about other things besides the just how much the previous workout kind of beat you up. A couple more things I think are going to be useful.

01:48:00 Leveraging The Visual System During Effort, Milestones; Dilation & Contraction; Pacing

And I do want to just pack these in, 'cause we are closing out the month on physical performance. And that's about programming and about pacing and the kind of mental aspects of endurance. So let's start with pacing and mental aspects of endurance. I learned from a friend and colleague here at the podcast that... Who's very active in triathlon and marathon and other... Knows a lot about that whole world and the

competitive landscape there, that pacing and literally physical pacers have a laser on the ground or visualizing or having a pace car or a pace runner in front is actually not allowed in many competitions. And if those are present doesn't allow the race times to qualify as legitimate record holding times. And that's very interesting to me because what we know is that the visual system has this capacity to switch back and forth between what we call panoramic vision where we're not really focused on anything. Things are just flowing past us or our eyes are just kind of zoned out. So I can do this right now and you won't be able to tell but I'm looking at the corners of the room. I see Costello down there on the floor. I see my podcast team here and I can also see the microphone. I can see myself in this environment. That's panoramic vision. Whereas if I draw my eyes to one location like right there in the center of the camera, it's what's called a vergence eye movement. So I'm contracting my visual window. The contraction of the visual window when that's done, is the same thing that would happen if I was tracking say a pace car or a pace runner or a laser on the ground. The mere bringing our eyes together to what we call a vergence point has the impact of triggering the activation of neural circuits in the thalamus. Things like zona incerta, if you really want to know what their names are, of these brain areas. As well as in the brainstem that activate the so-called alertness system, things like locus coeruleus, whereas panoramic vision tends to bring us into states of relaxation. You can actually leverage us during your runs. Let's say you're out for a long run or you're swimming or you're cycling. This is probably easiest to imagine out of the water before I do in the water as well. If you focus your attention on a landmark that you're going to run to, you'll find that it's much easier than if you don't actually have a set milestone or landmark that you're going to run to. However, if you were to continue that repeatedly just going milestone after milestone, after milestone, you would feel more mentally fatigued and you would actually be able to degenerate less work overall. One thing that can be useful is focusing on a milestone, running to that milestone or biking whatever it is the activity happens to be, and then dilating your field of view to relax the system and then continuing again. So it's this kind of active contraction or of the visual window and then dilation of the visual window. Contraction of the visual window allows you to generate more effort but there's a cost to doing that, because neurons consume energy. And now you know how they do that. Whereas dilation allows you to essentially be more efficient, right? Now, pacing is not allowed or having a pacer, a visual pacer because it does allow you to access systems in the brain and body that allow you to create more energy, more effort. And so I find it

interesting that I think in a kind of subconscious genius the race officials and the governing bodies of these races have said, okay, sure, having a pacer there or someone in front, you can draft off of them, there's actually a kind of a aerodynamic effect of having someone in front of you that makes it easier to run in the wake of their airstream. So to speak. Same as true in cycling. This is why the cycling teams are so good at maneuvering and packs. In very specific ways, you can go faster with less effort if you're drafting as it's called behind somebody. But as well where you place your vision will allow you to generate more effort. And so it's interesting that they've taken out this kind of, if you will, performance enhancing tool. I imagine and I have to imagine it's the appropriate word here. That good runners, good cyclists have the ability to create a kind of pacer in their minds eye. I have to imagine that they're not just completely allowing their attention to drift, although they do that when they want to be in highly efficient mode generating effort without having to tax their mental capacity. And remember mental capacity is neural energy and consumes glucose energy that they could devote to the functioning of their body. But that when needed that they can focus their energy in, and actually kind of chase a mental pacer or pick milestone. So this is a mental game that you can play as well. It's a little bit hard to do in the context of weightlifting in the gym. It's more of a moving through space kind of thing, but some people do this by counting reps, et cetera. I think it's especially suitable for endurance type of exercise, especially done outside. One of the reasons I hate running on a treadmill is it just feels like it's never ending. And I've never tried one of these Peloton things. I try and avoid looking at screens as much as I possibly can. But if you try this next time you're out for a run or a swim.

01:53:10 The Physiological Basis of Your “Extra Gear”, Accessing Your “Kick”, Steve Prefontaine

What you'll find is that you have a capacity to engage a system of higher energy output when you focus your eyes on a particular location, but you want to use that judiciously because your goal of course, is to become efficient at moving through space over time and not taxing your brain and body to the point where you arrive at the end of that, unless it's race day just completely tapped out. So that's a kind of interesting aspect of running. If you're a fan of running, which I am, and you get the chance to look at any of the documentaries or docu-drama has made about, [clears throat] excuse me, about

Steve Prefontaine. It was clear that he was mostly in a battle with himself, but that he was also a highly competitive individual. And you'll see this in some of his races. I do encourage you to look some of those up on YouTube or see the docudramas. They're quite good. Where he ran the... Essentially was 12 laps on a track. It's essentially the five. It is the 5,000 meter race where essentially three miles. And he essentially tried to sprint the whole thing which is ridiculous. Actually knowing what you know today you'll realize that Steve Prefontaine basically was pulling from strength, speed, power, muscular, endurance, long duration effort, high intensity, aerobic, anaerobic as he sort of tried to maximize every fuel system. And you'll see that in the races that he runs, but that when runners are nearing the final laps, the so-called bell lap of a race, they'll often look to one another to see where somebody is obviously to assess their progress and how close somebody is? But when somebody gets past, oftentimes you'll see someone access this mysterious kick, this ability to tap into some additional gear that allows them to run forward or faster when they themselves actually thought that they were maxed out. So someone could be running for the finish line. They're convinced they're going to win. They're going max effort or at least they perceive max effort. Someone passes them. And all of a sudden max effort has changed, because of that visual target they are able to access higher levels of speed and output and effort and performance. They don't always catch up to that person and win, but having a target a milestone is a powerful way that we can generate more force and energy in anything. And the visual system is the way that we bring those milestones into our brain, which then brings about epinephrin, which brings about neural firing, which allows us to access whatever resources happen to be available to us. So I find this fascinating because people often wonder, like where does the kick come from? Where is this kind of gift of an additional gear? Where is that deeper resource? And we often express it and talk about it, in kind of psychological terms like heart or willpower or that something kind of got transplanted into us or descended into us. And not to remove any of the spiritual aspects of sport or running or effort of the human, you know, heart.

01:56:00 Programming Examples; Concurrent Training

But it's very clear that the nervous system when it has a specific visual target can generate the sorts of intense effort that it couldn't otherwise. And it sometimes even comes as a surprise to the person generating the effort. I promised that I would talk

about programming, meaning when and how many times a week to do the various workouts related to endurance and how to merge those with other types of exercise that you might be doing for strength or yoga or other things that you might be doing like work and other things, unrelated to exercise. Since that's a vast space with many different parameters and you all have different lives and lifestyles and backgrounds with fitness, et cetera. What I'm going to do is I'm going to put three different levels if you will or protocols that one could adopt in a link on the show notes. So in the caption on YouTube, if you click on that link, you'll be able to see three possible combinations of endurance work, strength, and hypertrophy work or endurance work, flexibility and hypertrophy work that are grounded in many of the major publications that Dr. Andy Galpin and colleagues and other people have described including this review that's also linked there on concurrent training and how one can use concurrent training, meaning training for endurance, training for strength, training for hypertrophy, training for all these different things without having to train constantly everyday twice a day, et cetera. So if you are interested in taking the protocols that you learned about in this episode and in previous episodes and combining those, we've placed them there for you as a completely zero cost resource. Please understand they are not wholly... Costello agrees. They are not wholly. There will be variation in terms of what people can tolerate and what they have time for? But I think they'll serve as a useful guideline in getting started or in continuing with an expanding on existing endurance work, strength work, hypertrophy work and so forth. Just really quickly.

01:57:57 Caffeine, Magnesium Malate to Reduce Soreness, Nitric Oxide, Beta-Alanine

We didn't talk about supplements much today. In the previous episodes I talked about the phosphocreatine system and supplementing with creatine, I talked about beta alanine for kind of moderate duration work. You know really the only things that have been shown to really improve endurance work across the four varieties of endurance work I described today. They have essentially two forms. One, are stimulants. So things like caffeine will definitely improve endurance work and power output. There's a little bit of evidence that caffeine intake can actually inhibit the function of the creating system, but it's just one study. But that's interesting. If you want to read that study, you can put caffeine into [www.examine.com](http://www.examine.com) and it will take you to that study. Many people get sore after workouts, in particular workouts that involve a lot of eccentric loading or workouts

that are very novel where they've kind of pushed it instead of moving gradually as I suggest into say high intensity anaerobic endurance work of three sets of 20 seconds on 100 seconds rest. Maybe you get over ambitious and you do eight sets. In which case you are extremely sore. Certain forms of magnesium in particular, magnesium malate, M-A-L-A-T-E. Have been shown to be useful for removing or reducing the amount of delayed onset muscle soreness. That form of magnesium is distinctly different than the sorts of magnesium that are good for getting us into sleep. Things like magnesium three and eight and Bisglycinate. And then there's this whole thing about beet powder and beet juices and things that increase nitric oxide and allow for more vasodilation and therefore delivery of blood to muscle and neurons and other tissues for long bouts of endurance work. Some people like beet juice and they related compounds that increase arginine and vasodilation. Some people don't. Some people don't feel good when they take those. Some people also don't feel good when they take beta alanine, because it can give them this feeling of kind of like itchy, creepy crawlies under the skin kind of the niacin phenomenon, the niacin flush. Some people don't mind that, or some people don't experience that.

02:00:00 Synthesis; Next Episodes, Zero-Cost Ways to Support, Sponsors, Sources

So when it comes to supplementation there's a lot of variety. But magnesium malate has been shown to reduce soreness as sometimes that's good. Cold and hot contrast therapy for soreness things of that sort. But in general, we focused mainly today on behavioral tools. You'll notice that all of the tools are accessible without the need for lots of equipment. So I didn't say you need a rower, or you need a kettlebell though those will work. And I hope I was able to illustrate for you that endurance isn't just one thing. It's not just the ability to go for long bouts of exercise of different kinds, that there's also this mental component because of the way that neurons work. And also that there are these different forms of endurance of muscular endurance, that where you're going to fail 'cause of the muscles and muscle energy utilization and the nerves that innervate those muscles locally not because of a failure to bring in oxygen or blood. Whereas long duration effort. It's going to be more about, you know, being below your VO2 max, and your ability to be efficient for long bouts of more than 12 minutes of exercise. One set, as they say of 12 minutes to maybe several hours. I should just mention with long duration type work. You know, you could even imagine raking in the yard or mowing a lawn



depending on how big that lawn is. I use to have job when I was a kid mowing lawns and I'll tell you, we didn't have many neighbors with very big lawns, but there are a few of them felt huge 'cause they were really convoluted. And if you're pushing that mower, and these were the old fashioned mowers not electric mowers, it's work. That's also of the sort that we call long duration endurance work. High intensity training we'll tap into yet other fuel sources and mechanisms as we learned today. So if you are enjoying this podcast and you're finding the information useful, it would be great if you would subscribe to the YouTube channel that really helps us quite a lot. And if you like, you can click the notifications button on YouTube as well. That way you're sure to never miss an episode. We always release episodes on Monday, but we also saw sometimes release episodes in between Mondays. So please do subscribe to the YouTube channel. Please also give us feedback in the comment section on the YouTube channel. That's where you can tell us about topics that you want to hear more about. Or if you have questions about a given episode or content within an episode, that's where you want to put that feedback. If you're not already subscribing on Apple and Spotify as well, please do that. On Apple you can give us up to a five-star review. We like to think that you would give us a five-star review. But you can also leave comments on Apple about the podcast more generally. And again, those are all zero cost ways that you can really help support the podcast. We do have a Patreon. It is [www.patreon.com/andrewhuberman](http://www.patreon.com/andrewhuberman), at [www.patreon.com/andrewhuberman](http://www.patreon.com/andrewhuberman). You can support the podcast at any level that you like. Please also check out our sponsors that we mentioned at the beginning of the podcast. I know ad reads are not the first thing that people want to hear when they're getting ready to consume scientific information. Please understand that the ads and the sponsors allow us to bring the zero cost to consumer information about science and science-related tools to everybody. So if you have the means, check out the sponsors. We only work with sponsors whose products we really believe in and that I actually use and really love. There's no obligation, however. And we do talk about supplements from time to time. Again, no obligation to use supplements. We also talk about behavioral tools, but if you are interested in supplements, please go to [www.examine.com](http://www.examine.com) to evaluate those supplements and their various effects. If you're curious about that. And we work with Thorne, T-H-O-R-N-E. Thorne is a supplement manufacturer that we believe has the highest levels of stringency in terms of the quality of the supplements. And they are very precise and very stringent about the amounts of each of those compounds in the given supplements. This is a huge problem elsewhere in the

supplement industry. Many brands don't include what they say they include on the bottle. It seems to show up every time people test different brands. But Thorne continually tests out with the highest levels of accuracy and stringency. If you want to see the supplements that I take, you can go to [www.thorne.com/u/huberman](http://www.thorne.com/u/huberman). And if you do that you can see all the supplements that I take. You can get 20% off any of those supplements as well. If you want to navigate into the main Thorne site and you see a supplement that you're interested in, you'll also get 20% off any of those supplements as well. So that's [www.thorne.com/u/huberman](http://www.thorne.com/u/huberman). So we have both cost-free and other ways to help support the podcast. If you know people that might be interested in the podcast and benefit from the information, please recommend it to them. That really helps us. If you're on Instagram, check us out @hubermanlab. If you're on Twitter, it's also @hubermanlab. And please check out our new website which is [www.hubermanlab.com](http://www.hubermanlab.com). There you can find all the episodes of all the podcasts batched according to topic in every format, YouTube, Apple and Spotify with links out to those. It's searchable by keywords that you're interested in. So sleep or exercise, weight training, strength, fat loss, et cetera. And you can subscribe to our newsletter, the Neural Network which will allow you to get zero cost updates about speaking events, about any book releases or exciting things that I'm reading that I think you would enjoy reading as well. As well as protocols related to science in some summary and important notes from the podcast. And last but not least on behalf of myself and Costello who's finally waking up for... Oh, no, he went back to sleep. Thank you for your interest in science.