Improve Flexibility with Research-Supported Stretching Protocols | Huberman Lab Podcast #76

In this episode, I explain the science behind limb range of motion and flexibility and how to increase them by using science-supported protocols. Flexibility is crucial for physical movements and can help prevent injuries, decrease inflammation, modulate physical and mental pain, impact exercise recovery speed and even potentially slow the progression of certain diseases. I explain the biology of flexibility, including the specific neural mechanisms that sense stretch and load (i.e., tension) on the muscles and limbs, as well as how specific brain regions like the insula combine those signals to ultimately control limb range of movement. I also provide science-based stretching and “micro-stretching” protocols that reliably improve limb flexibility with the minimum necessary time investment. I review all the details of those stretching protocols: how often to do them, for how long, their timing relative to other exercises, sets, the time between sets, measuring progress and more. All people, physically active or not, should benefit from the information and tools described in this episode.

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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. Today, we are going to discuss the science and practice of flexibility and stretching. Flexibility and stretching are topics that I believe do not receive nearly as much attention as they deserve. For most people, the topics of flexibility and stretching bring to mind things like yoga, injury prevention, or maybe even contortionism. But it turns out that flexibility and stretching are features that are built into our basic body plan. Young children, young animals, and adults, and, indeed, older children and animals all stretch and all have some degree of flexibility. It turns out that having flexibility, and our ability to stretch, and the interaction between stretching and flexibility are fundamental to how we move, our ability to learn new movements, indeed also to prevent injury or repair injuries, and to offsetting and reducing inflammation throughout the body. In fact, today I'm going to share with you a remarkable set of studies that show that stretching can actually adjust things like tumor growth. This is work that was done by one of the major directors of the National Institutes of Health. So, today's discussion will start with a description of the mechanisms, literally the cells and the connections from your nervous system that mediate flexibility and stretching. And I promise that I'll make that information accessible to you whether or not you have a biology background or not. Then with that information in hand, I'm going to present to you what the scientific literature says about the best times and ways to stretch, everything right down to the detail of how long to hold a stretch, whether or not to hold a stretch at all because it turns out there are multiple kinds of stretching. So, you can imagine you have stretches where you hold the stretch for a very long time and use as little momentum as possible, and then there's also what's called dynamic and ballistic stretching where you're literally swinging your limbs trying to increase the range of motion. I will explain the science and application of flexibility and stretching in the context of sports performance, whether or not you are engaging in cardiovascular exercise, or resistance exercise, or both, whether or not you're a competitive athlete or simply a recreational exerciser, as I am, whether or not you are trying to increase your range of motion and flexibility for longevity purposes, or whether or not you're trying to do it in order to access different parts of your nervous system 'cause we'll soon learn today that your ability to improve flexibility and, indeed, to engage in specific stretching exercises can actually be used to powerfully modulate your ability to tolerate pain, both emotional and physical pain. So, this thing that we call flexibility and stretching is actually a vast landscape. We're going to simplify and organize all that for you today and by the end of today's episode, you're going to have a number of simple, easy-to-apply tools

00:02:57 Thesis, InsideTracker, Eight Sleep

that are grounded in the best scientific research that you can apply for your specific goals. Before we begin, I'd like to emphasize that 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 Thesis. Thesis makes custom nootropics that are designed to get your brain and body into the optimal state for the cognitive and physical things that you need to perform at the highest level. I have to confess, in fact I've said it many times before, I am not a fan of the word nootropics because it means smart drugs. And frankly, as a neuroscientist, I'd be remiss If I didn't acknowledge that there's really no circuit in your brain for being smart, you have neural circuits in your brain that are designed to get you to focus very well, or to task switch very well, or to be creative. Thesis understands this, and as a consequence they've designed nootropics that are tailored to your specific needs in the cognitive and physical realm. What I mean by that is if you go to the Thesis site, you fill out a short quiz, and they'll give you the opportunity to try a small kit of different nootropics with different ingredients. You have the opportunity to try several different blends over the course of the month and discover which nootropics works best for your unique brain chemistry and genetics. I've been using Thesis for about eight and a half months now, and I can confidently say that their nootropics have been a game changer. To get your own personalized nootropic starter kit, you can go online to takethesis.com/huberman. There you'll find that three-minute quiz and Thesis will send you four different formulas to try in your first month. That's takethesis.com/huberman, and use the code HUBERMAN at checkout to get 10% off your first box. Today's episode is also brought to us by InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better understand your body and help you reach your health goals. I've long been a believer in getting regular bloodwork done for the simple reason that many of the factors that impact your immediate and long-term health can only be analyzed from a quality blood test. One issue with a lot of blood tests and DNA tests out there is that you get information back about hormone levels, metabolic factors, et cetera, but you don't know what to do with that information. InsideTracker has a very easy to use personalized platform that lets you look at those numbers and then you can literally move your cursor over those numbers and there are little popup windows that will tell you the things that you can do in terms of lifestyle, so exercise, and nutrition, supplementation, and so on to bring those numbers into the ranges that are optimal for you. So, it really takes all the guesswork out of what to do with that bloodwork and DNA information. If you'd like to try InsideTracker, you can visit insidetracker.com/huberman to get 20% off any of InsideTracker's plans, just use the code HUBERMAN at checkout. That's insidetracker.com/huberman to get 20% off any of InsideTracker's plans, again, just use the code HUBERMAN at checkout. Today's episode is also brought to us by Eight Sleep. Eight Sleep makes smart mattress covers that have cooling, heating, and sleep tracking capacity. And, indeed, you can dial in, you can literally program the temperature of your sleeping environment from the time you go to sleep until the time you wake up in the morning. This turns out to be immensely powerful because as I've talked about on the podcast before, in order to fall asleep and stay deeply asleep throughout the night, your body has to drop by about one to three degrees, and waking up in the morning actually involves a warming up of your body temperature. For many people, they just can't precisely control their sleep environment well enough in order for all that to go well. I was one such person. So, for a long time I'd fall asleep pretty easily, but then I'd wake up in the middle of the night, I tended to run warm, but then sometimes I'd feel really tired in the morning as if I couldn't wake up. I started sleeping on an Eight Sleep mattress cover. I programmed it so that the temperature would be rather cool in the early part of the evening when I would get into bed and then would drop into the deeper phases of the night when I was entering deep sleep and then rapid eye movement sleep, and then would warm towards morning, it would help me wake up quickly. And as a consequence, I'm sleeping throughout the night now and I'm waking up feeling completely refreshed. If you'd like to try an Eight Sleep mattress cover, you can go to eightsleep.com/huberman to check out the Pod Pro Cover and save $150 at checkout. Eight Sleep currently ships within the USA, Canada, and the United Kingdom.

00:07:22 Innate Flexibility

Again, that's eightsleep.com/huberman to save $150 at checkout. Let's talk about flexibility and stretching. Before we talk about the practices of flexibility and stretching, I'd like to just highlight some of the features that are already built into your nervous system and into your body that allow you to be flexible. Some of us feel tighter than others, sometimes in specific limbs or areas of our body, some people feel really loose and limb, some people even have what's called a hyper-flexibility. I, for instance, have a relative that can take her fingers and bend them back to the point where they touch her wrist. And it always makes me cringe a little bit, but she can do that without any pain, she seems to have some hyper-flexibility in her joints. I do not have that feature. Some of you may find that you are more flexible than others naturally, and some of you might be thinking you don't need to build in additional flexibility. Well, I think by the end of today's episode, you'll realize that almost all of us can benefit from having some sort of understanding about flexibility and having some stretching protocol that we incorporate into our life, if not just for physical performance reasons and for postural reasons, then also for cognitive and mental reasons, and I'll be sure to clarify what all of that means. Right now, I'd like to take a moment and just highlight the flexibility that you already have. For instance, if you were to move your arm behind your torso a little bit and then sort of let go or stop exerting any effort in doing that, you would find that the limb would return more or less to a position next to your torso, at least I would hope so. And why is that? Well, it turns out that there are aspects of your nervous system, aspects of your skeletal system, aspects of your muscles, and aspects of the connective tissue that binds all of that together, that try and restore a particular order or position to your limbs and your limbs relative to one another. So, that reflects a very specific set of processes that it turns out are the same set of processes

00:09:23 Movement: Nervous System, Connective Tissue & Muscle; Range of Motion

that you use when you are trying to enhance flexibility and stretching. So, I'd like to just take a moment and review the basic elements of nervous system, muscle, connective tissue, and skeletal tissue, bone, that allow for flexibility and stretching. And here we can point to two major mechanisms by which your nervous system, neurons, meaning nerve cells, communicate with muscles, and those muscles communicate back to your nervous system to make sure that your limbs don't stretch too far, they don't move too far such that you get injured. And in addition to that, mechanisms that ensure that you don't overload your muscles too much with weight, or with tension, or with effort and damage them that way. 'Cause it turns out that the second security mechanism of making sure that you don't overload muscles can be leveraged toward increasing your flexibility almost immediately. That's right, there are protocols and tools that I'll share with you that are going to allow you to vastly improve your flexibility over time. But there are also mechanisms that allow you to quite significantly increase your degree of flexibility in a very short period of time, and within just a few seconds. So, let's establish some of the basic biological mechanisms. Any time we talk about biology or physiology, we're going to talk about structure, meaning the cells and their connections, and functions, what they do. There are just a few names to understand, you do not have to memorize these names. The important thing that I'd like you to know is that flexibility and the process of stretching and getting more flexible involves three major components, neural, meaning of the nervous system, muscular, muscles, and connective tissue. Connective tissue is the stuff that surrounds the neural stuff and the muscular stuff, although it's all kind of weaved together and braided together in complicated ways. Some of you may have heard of fascia. We're going to talk a little bit about fascia today, although it's such an interesting tissue that's really deserving of its own episode. Fascial tissue, we're going to talk about some of the stuff that surrounds muscles that really gives you your shape, and holds everything together, and allows for flexibility to occur. So, here's a key thing that everyone should know whether or not you're talking about flexibility or not. Your nervous system controls your muscles, it's what gets your muscles to contract. So, within your spinal cord, you have a category of neurons, nerve cells, that are called motor neurons. To be precise, they are lower motor neurons 'cause they're in your spinal cord. We call them lower to distinguish them from the motor neurons that are in your brain up in your skull. Those lower motor neurons, hereafter I'll just refer to them as motor neurons. If I want to talk about the other kind of motor neurons, I'll say upper motor neurons. So, if I say motor neurons, I just mean the ones in your spinal cord. Those motor neurons send a little wire or set of wires out to your muscles, and that creates what's called a neuromuscular junction, which just means that the neurons meet the muscles at a particular place. Those neurons release a chemical, that chemical is called acetylcholine. Some of you may have heard about acetylcholine before, acetylcholine also exists in your brain and does other things in your brain, mainly it's involved in focus and attention. But at the neuromuscular junction, the release of acetylcholine from these nerve cells, these neurons, onto the muscles causes the muscles to contract. And when muscles contract, they are able to move limbs by way of changing the length of the muscle, adjusting the function of connective tissue like tendons and ligaments. And for instance, if you're bringing your wrist closer to your shoulder, that biceps muscle is contracting, it's getting shorter. I mean, in reality it hasn't gotten shorter overall, it's just temporarily shorter, of course. All of that is controlled by neurons. And it's those motor neurons from the spinal cord that are really responsible for the major movement of your limbs by way of causing contraction of specific muscles at specific times. So, the key thing to take away is that nerve controls the contraction of muscles. Now, within the muscles themselves, there are nerve connections. And these are nerve connections that arise from a different set of neurons in the spinal cord that we call sensory neurons. The sensory neurons exist in a different part of the spinal cord, and they send a low wire or set of wires into the muscles. And there's a particular kind of sensory neuron that comes out of your spinal cord and into your muscles, which are called spindle neurons. They create or they actually wrap around muscle fibers, kind of corkscrew around them and give kind of a spring-like appearance. And for you aficionados out there, these are intrafusal connections or neurons. Intrafusal means within the muscle, but you really don't need to know that unless you're really curious about it, or you're going to become a neuroscientist, or you're in medical school or something. These spindle connections within the muscle that wrap around the muscle fibers sense the stretch of those muscle fibers. So, now we have two parts to the system that I've described. You've got motor neurons that can cause muscles to contract and shorten, and we have these spindles within the muscles themselves that wrap around the muscle fibers, and that information is sent from the muscle back to the spinal cord. It's a form of sensing what's going on in the muscle. Much in the same way that you have neurons in your eye that sense light in your external environment, you have neurons in your ear that sense sound waves in your external environment, you have neurons in your spinal cord that are sensory neurons that are sensing the amount of stretch in the muscles. What happens is if a given muscle is stretching really far, those sensory neurons, those spindles within the muscle will activate and will send a electrical potential, literally a bit of electricity along that wire's length into the spinal cord. And then, within the spinal cord that sensory neuron communicates through a series of intermediate steps, but to the motor neuron and makes sure that that motor neuron contracts. Now, why would that be useful? Well, what this does is it creates a situation where if a muscle is or is stretching too much because the range of motion of a limb is increased too much then the muscle will contract to bring that limb range of motion into a safe range again. Now, what determines whether or not a range of motion is quote-unquote safe or not is dictated by a number of things. It's dictated by things that are happening in this kind of loop of neural connections in the spinal cord and muscle. It's also determined by what's going on in your head, literally in your mind cognitively about whether or not the movement of that limb its increasing range of motion is good for you, whether or not you're doing it deliberately, whether or not it's bad for you. And then there are also some basic safety mechanisms that are put in there that really try and restrict our limb range of motion.

Okay, so just to clarify, this whole thing looks like a loop, and the essential components of the loop are motor neurons contract muscles, sensory neurons, of which there are a bunch of different varieties, well, in this case, what we're calling the spindles are sensing stretch within the muscles. And if a given muscle is elongating because of the increased range of motion of a limb, those sensory neurons send an electrical signal into the spinal cord such that there is an activation of the motor neuron, which by now should make perfect sense as to why that's useful. It then shortens up the muscle. It actually doesn't really shorten the muscle, but it contracts the muscle that brings the limb back into a safe range of motion. Okay, so this process is very fast, it was designed to keep your body together and safe. It's designed to make sure that you don't take your arm and swing it behind your torso and it just goes all the way back to the middle of your back. I mean, unless you're a contortionist or you've trained that kind of level of flexibility, that would be terrible because it could provide a lot of damage to the muscles, and to the connective tissue, and so forth. So, that's one basic mechanism that we want to hold in mind,

00:17:51 Golgi Tendon Organs (GTOs) & Load Sensing Mechanisms

this idea of a spindle that senses stretch and can activate contraction of the muscles and shorten the muscles. The next mechanism I want to describe, and once again there are only two that you need to hold in mind for this episode. This other mechanism has a lot of the same features as the one I just described, but it has less to do with stretch, in fact, it doesn't have to do with stretch as much as it has to do with sensing loads. So, at the end of each muscles you have tendons typically, and there are neurons that are closely associated with those tendons that are called Golgi tendon organs, right? These are neurons that are sensory neurons that sense how much load is on a given muscle. Right, so if you're lifting up something very, very heavy, these neurons are going to fire, meaning they're going to send electrical activity into the spinal cord. And then, those neurons have the ability to shut down, not activate, but shut down motor neurons and to prevent the contraction of a given muscle. So, for instance, if you were to walk over and try and pick up a weight that is much too heavy for you, meaning you could not do it without injuring yourself and you start to try and heave that weight off the ground. There are a number of reasons why you might not be able to lift it, but let's say you start to get it a little bit off the ground, or you start to get some force generated that would allow it to move. But the force that you're generating could potentially rip your muscles or your tendons off of the bone, right, that it could disrupt the joints and it could tear ligaments. Well, you have a safety mechanism in place, it's these Golgi tendon organs, these GTOs, as they're called, they get activated and shut down the motor neurons and make it impossible for those muscles to contract. Okay, so on the one hand, we have a mechanism that senses stretch and can figure out when stretch is excessive. And when this system detects that stretch is excessive, it activates the contraction of muscles. And then, we have a second mechanism that senses loads, and when tension or loads is deemed excessive by these circuits, and remember these circuits don't have a mind, they don't go, "Oh, this is excessive," they just sense loads. And when those loads exceed a certain threshold, well then those GTOs, those Golgi tendon organs, send signals into the spinal cord that shut down your motor neuron's ability to contract muscle so that you no longer can lift that heavy load. So, both of these are protective mechanisms, but both of these can be leveraged in a very logical way

00:20:20 Decreased Flexibility & Aging

and in a very safe way in order to increase your limb range of motion. So, there are a couple of things I want to point out before going a little bit further into how your nervous system controls flexibility and stretching, and those key points are the following. There are now dozens if not hundreds of studies that show that a dedicated stretching practice can improve limb range of motion. Now, for many of you listening, you're probably saying, "Duh," but I think it's important to point that out, that a dedicated stretching practice can increase limb range of motion. And as you'll soon learn, there are specific mechanisms that can explain that effect. The second point is one of longevity. And when I say longevity, I don't necessarily mean late-stage aging. We all undergo a decrease in limb range of motion, unless we do something to offset that decrease. And the current numbers vary from study to study, but if you look en masse, you look at all of those studies and what you basically find is that we start to experience a decrease in flexibility from about age 20 until about age 49 that's pretty dramatic. And then, of course, it will continue after age 49, but basically it's a 10% decrease every 10 years. So, we could say it's a 1% decrease per year, although it's not necessarily linear. What do I mean by that? Well, it's not necessarily that on your 21st birthday, you are 1% less flexible than you were on your 20th birthday and it decreased by 1% per year, some of these changes can be non-linear. So, you can imagine the person who's doing just fine in terms of flexibility between 20 and 30, and then they get to 32 and suddenly they've lost 5% of their flexibility. Now, of course, there will be a ton of lifestyle factors. If you're a regular practitioner of yoga, if you have a dedicated stretching practice, if you're doing other things to improve your muscle contractibility, so you're doing resistance training it turns out can actually indirectly improve flexibility. There are a number of different factors, but the key point is that maintaining some degree of flexibility and maybe even enhancing range of motion and flexibility is of immense benefit for offsetting injury provided it's not pushed too far. There are a number of people who have pushed their limb range of motion so far that they experience all sorts of injuries,

00:22:38 Insula, Body Discomfort & Choice

both acute and chronic injuries. Today, we'll also talk about how to avoid those scenarios. Okay, so we've established that there are mechanisms within the spinal cord, muscles, and connective tissue, those remember it's the motor neurons, the spindles, the GTOs, and, of course, the muscles themselves, and connective tissue, tendons, but also other forms of connective tissue that establish whether or not a limb is going to stay within a particular range of motion or not, and whether or not a limb is going to be allowed by the nervous system to pursue or handle a given load, a given tension. There are also mechanisms that arrive to the neuromuscular system from higher up in the nervous system, from the brain. And those mechanisms involve a couple of different facets that are really interesting, and I think that we should all know about. In fact, today, I'm going to teach you about a set of neurons that I'm guessing 99.9% of you have never heard of, including all you neuroscientists out there, if you're out there, and I know you're out there, that seem uniquely enriched in humans and probably perform essential roles in our ability to regulate our physiology and our emotional state. So, within the brain, we have the ability to sense things in the external world, something we called exteroception, and we have the ability to sense things in our internal world within our body, called interoception. Interoception can be the volume of food in your gut, whether or not you're experiencing any organ pain or discomfort, whether or not you feel good in your gut and in your organs, that's actually a kind of feeling, "Hmm, I feel great, I feel sated, I feel relaxed," but those are all different forms of interoception. The main brain area that's associated with interpreting what's going on in our body is called the insula, I-N-S-U-L-A.

It's a very interesting brain region, it's got two major parts. The front of it is mainly concerned with things like smell, and to some extent vision, and to some extent other things that are arriving from the external world and combining with what's going on internally and making sense of all that, or at least routing that information elsewhere in your nervous system to make decision, like if you smell something good to approach it, or if you smell something bad to avoid it. The front of the insula is really doing all of that kind of stuff along with other brain areas. The posterior insula, the back of the insula that is, has a very interesting and distinct set of functions. The posterior insula is mainly concerned with what's going on with your somatic experience. How do you feel internally? And how is the movement that you happen to be doing combining with your internal state to allow you to feel, as I like to say the nervous system mainly batches things into yum, like, "Oh, this is really good for me," yuck, "This is really bad for me and I need to stop," or meh, "This is kind of neutral." Okay, so this isn't about food, but we could say for most stimuli, most senses, whether or not they're senses of things internally or externally, our nervous system is trying to make decisions about what to do with that information, and so it mainly batches information into yum, I want to keep doing this or approach this thing, or continue down some path of movement, or eating, or staying in a temperature environment, et cetera, or yuck, I need to get out of here, I don't want any more of this, I don't want to keep doing this, this is painful, or aversive, or stressful. And then meh, so if it doesn't really matter, I can just kind of stay right here or not. Yum, yuck, and meh. Well, in your posterior insula, you have a very interesting population of very large neurons, these are exceptionally large neurons called von Economo neurons. These are neurons that are, again, unbeknownst to most neuroscientists and they seem uniquely enriched in humans. Chimpanzees have them and some other large animals have them. So, they're found in whales, chimpanzees, elephants, and in humans. But even though we are much smaller than most whales and even though we are much smaller than most elephants, I mean, remember there are baby elephants. As far as I know, they haven't bred up like mini-elephants yet, they seem to have a teacup version of pretty much every dog breed. You can look that up, I certainly have mixed feelings about this notion of trying to downsize everything to the point where you could kind of like the pocket-sized bulldog I think of someday will arrive. I'm not a fan of that kind of downsizing of different breeds, but because there aren't teacup elephants and teacup gorillas, and teacup chimpanzees, and so forth, most all of those other species are larger than us. They have these von Economo neurons and we have these von Economo neurons, but we have in upwards of 80,000 of these things in our posterior insula. These other species tend to have somewhere in the range of 1,000 to maybe 10,000 or so. Why is that interesting? Well, these von Economo neurons have the unique property of integrating our knowledge about our body movements, our sense of pain and discomfort, and can drive motivational processes that allow us to lean into discomfort and, indeed, to overcome any discomfort if we decide that the discomfort that we are experiencing is good for us or directed toward a specific goal. This knowledge turns out to be very important to keep in mind because as we migrate this conversation toward the things that we can do to enhance flexibility and stretching, you'll soon learn that there are moments within a stretching protocol where you have the opportunity to either override pain and discomfort to kind of relax through it or push through it. Right, there's a decision fork in the road there, and it'll tell you which fork in the road to take, or to say, "Uh-uh, I'm not going to do that. I'm going to allow these natural reflexes of the spindle to kick in and just essentially stop me from stretching if a given limb isn't designed or shouldn't be stretched that far." So, I'd like you to keep these von Economo neurons in mind. I should mention they're named von Economo because the guy, Constantin von Economo, that discovered them at the end of the 1800s, early 1900s, decided to name them after himself, as many scientists do, or certainly the neurologists and physicians are famous for naming things after themselves. These von Economo neurons turn out to be very important to keep in mind as we embark on our exploration of what sorts of stretching practices can be best applied to increase flexibility because whether or not you undertake a mild, moderate, or intense flexibility training, you will no doubt encounter a scenario at some point where you will have to ask yourself, "Do I quote-unquote relax into this stretch, or do I try and push through just a little bit of discomfort?" And I'll explain how to gauge that decision in a very specific and ideally safe way, and I'll give you some tools that will allow you to make that decision in a way that best preserves the integrity of those neural circuits that I described earlier and can keep you safe. These von Economo neurons sit in the exact position that one would want to be able to evaluate what's going on in the body,

00:30:02 von Economo Neurons, Parasympathetic Activation & Relaxation

in particular what's going on in terms of limb movements, how that relates to our feelings of discomfort. And then there's the other aspect of these von Economo neurons, which is that these von Economo neurons are connected to a number of different brain areas that can shift our internal state from one of so-called sympathetic activation. So, this is a pattern of alertness and even stress, sometimes even panic, but typically alertness and stress to one of so called parasympathetic activation to one of relaxation. Oftentimes, you'll hear that stretching should be done by relaxing into the stretch. Well, what does it actually mean to relax into the stretch? Well, these von Economo neurons sit at this junction where they're able to evaluate what's going on inside our body and allow us to access neural circuitries by which we can shift our relative level of alertness down a bit, or our relative level of stress down a bit and thereby to increase so-called parasympathetic activation and to literally override some of those spindle mechanisms, even the GTO mechanisms, but especially the spindle mechanisms at the neuromuscular and muscular spinal junction. And in that way, gently, subtly override the reflex that would otherwise cause us to contract those muscles back. The reason that's possible is because your brain has those other kinds of motor neurons, the upper motor neurons that can both direct, meaning control, and can override lower motor neurons. I'll give you a brief example of this that you've already done in your life, and that we all have the capacity for. What I'm referring to is the monosynaptic stretch reflex. This is something that every first year neuroscience graduate student learns, which is that if you were to step on a sharp object with a bare foot, you would not need to make the decision to retract your foot, you would automatically do that provided you have a healthy nervous system. There are mechanisms in place that cause the retraction of that limb by way of ensuring that the proper muscles contract and other muscles do not contract, in fact, that they fully relax. Okay, so in the case of stepping on a sharp object like a piece of glass, or a nail, or a tack, you would essentially activate the hip flexor to lift up your foot as quickly as possible. In doing so, that same neural circuit would activate a contralateral, meaning opposite side of the body circuit, to ensure that the leg, the foot that's not stepping on the sharp object would do exactly the opposite and would extend to make sure that you don't fall over. All of that happens reflexively, it does not require any thought or decision making. In fact, humans without any neocortex, literally that who decerebrate or an animal that doesn't have... When I say decerebrate, I mean lack of cerebral cortex. They can perform that because it's all controlled by circuits that are basically below the brain and in the spinal cord. There's a little bit of activation of circuits in the kind of deeper parts of the brain, but basically you don't need to think or decide in order to do that. However, if your life depended on walking across some sharp objects, let's say. Let's make it a little less dramatic so it's not like the "Die Hard" movie or something where he has to run barefoot across the glass, although that's a pretty good example of what I'm describing here, but let's say you had to walk across some very hot stones to get away from something that you wanted to avoid. You could override that stretch reflex by way of a decision made with your upper motor neurons, your insula, and your cognition, and almost certainly those von Economo neurons, which would be screaming, "Don't do this, don't do this, don't do this," could shuttle that information to brain areas that would allow you to override the reflex and essentially push through the pain. And maybe even, in fact, even not experience the pain to the same degree or even at all. So, these von Economo neurons sit at a very important junction within the brain. They pay attention to what's going on in your body, pain, pleasure, et cetera. And that includes what's going on with your limbs and your limb range of motion. They also are paying attention and can control the amount of activation, kind of alertness or calmness that you are able to create within your body in response to a given sensory experience. And as I mentioned before, they seem to be uniquely enriched in humans, they seem to be related to the aspects of our evolution that allow us to make decisions about what to do with our body in ways that other animals just simply can't. Before we go any further, I want to give you a practical tool that you can, of course, use, but that will also give you insight and experience into your muscle spindle spinal cord circuit mechanisms. So, what I'd like you to do is if you're in a proper place to do this, you're going to stand with legs straight, meaning knees not bent, and you're going to try and touch your toes, or for some of you that's going to be very easy and you might even be able to put your hands flat on the floor. I don't have that kind of flexibility, it's pretty easy for me to touch my toes. I don't care if you round your back or not, although ideally I would say don't round your back. Not because it's bad to do so necessarily, but just to try and keep this the same from trial to trial, as it were. So, try and get a sense of what your range of motion is in terms of bending over at the waist while maintaining a flat back and trying to touch your toes or even touch the floor. Maybe, again, you can even go hands flat to the floor or maybe even far out in front of you. Okay, now what I'd like you to do is stand back up and I'd like you to contract your quadriceps as hard as you possibly can for about 5-15 seconds. Let's say 10 seconds just to keep things more or less normalized. This obviously is not a super controlled experiment. So, to contract your quadriceps for those of you who don't know, you're going to extend your lower limb out. So, this would be like kicking, although don't do it too quickly, you're going to kick out your foot, you should feel your quadriceps contract on the top of your thighs. And you're going to try and consciously contract them as hard as you can. Okay, typically if you want to point your toe back towards your knee or shin that's also going to help somewhat to contract even harder and harder. Okay, so, do that for about 10 seconds. A lot of you will do this just while standing, contract, contract, contract. Okay, then release it, and then now go ahead and repeat that stretch where you're trying to touch your toes or touch the floor. So, this is, again, relying more or less on hamstring flexibility among other things. Okay, what most of you will find is that you have an immediate increase in hamstring flexibility, or your range of motion has increased. If you didn't experience that, then I would encourage you to try and contract your quadriceps harder and longer, so maybe 20 or 30 seconds, and then try this so-called experiment again. Why would contracting your quadriceps allow your hamstring flexibility to suddenly increase? Well, the way that our muscles are organized is such that we have muscles that are antagonistic to one another. So, our quadriceps and our hamstrings work in sort of a push-pull fashion, if you will. They can antagonize one another, so when you move your heel towards your glutes, you are using your hamstring, the hamstring obviously also does other things related to hip movement. And when you lift your knee or when you extend your foot and contract your quadriceps, you are essentially relaxing the hamstrings. Now, of course, most movements involve both quadricep and hamstring in synchrony. And that synchrony is really an elegant one, but here we're more or less isolating the quadriceps from the hamstrings, at least to the extent that it can leverage these spindle stretch mechanisms. So, what happens is when you contract your quadriceps hard, you are relaxing or releasing some of the stretch that's occurring in those intrafusal spindle sensory fibers going into your spinal cord. And as a consequence, you're able then to stretch your hamstrings further, or we can be more accurate and say that your range of motion about the hamstring and its related joints is greater when you aren't engaging that spindle reflex, which would cause the hamstrings to contract. Okay, so if you are somebody who has tight hamstrings, there could be a variety of reasons for that, but part of the reason is likely to be neural and you can release that neural spindle reflex by contracting the opposite antagonistic muscle, which in this case is the quadriceps. The same thing is true and can be leveraged for stretching other muscles. So, for instance, if you're going to do a tricep stretch, the typical kind of overhead where you grab your elbow and move it toward the midline of your body with using your opposite hand. Well, you can do that, and then I would suggest trying to flex your bicep, contract your bicep that is, while doing that. And for most people you'll notice a increase in the tricep range of motion or ability to kind of lean into, or to relax into, or to push that stretch, excuse me, a little bit further. Now, for you physios out there and for those of you that have backgrounds in kinesiology, I want to acknowledge, of course, there are other mechanisms that are coming into play. There are actually neural connections within the joints themselves that are providing proprioceptive feedback, et cetera, et cetera. But this is simply to illustrate that part of our range of motion is determined by these spindle mechanisms that I spent some time focusing on earlier. And indeed, this approach can be leveraged toward creating increased limb range of motion, not just for the hamstrings, but for your quadriceps. So, for instance, if you have tight quadriceps, you can do the opposite. You can contract your hamstring very intensely for let's say 10 seconds, or 20 seconds, or 30 seconds. So, that would take some conscious effort of bringing your heel up towards your glutes. You could do that in a way that you're really trying to contract those muscles hard, you'd have to use some deliberate hamstring activation there, meaning you have to use those upper motor neurons and the other aspects of your upper brain power, as it were, to try and really contract your hamstrings as intensely as possible, then you would relax that, and then you would do your quadricep stretch again. And if you did a pre-hamstring contraction measurement of your quadricep flexibility, and then you did a post-hamstring contraction measure of your quadricep flexibility, almost certainly you would find that that flexibility had increased. Now, of course, the muscle really didn't change much, the tendons didn't change much. What changed was the patterns of neural activation that were restricting you from in the first case stretching your hamstring or having a... To be more accurate we should say having a certain range of motion about the hamstring and its related joints and those brake mechanisms were removed. And, of course, then when you contract your hamstring, you're removing some of the neural brakes, the spindle acting as a brake and inhibiting that quadricep range of motion. Okay, so you can imagine this, and in fact you can apply this for any number of different muscles, the larger muscles and the sort of biceps, triceps, and hamstrings, quadriceps that are sort of the simplest place to think about this and to apply it. But in theory and, indeed, in practice, it really works for all the various muscle groups,

00:42:00 Muscle Anatomy & Cellular ‘Lengthening,’ Range of Motion

it's just sometimes harder to access these so-called antagonistic muscle groups. Now, we should take a moment and just discuss what actually happens as we get more flexible in the short-term and long-term. I just mentioned what happens in the short-term, clearly those don't involve lengthening of the muscles. It's not like the muscles slide along the bones or that the tendons really stretch out that much more than they had prior to that kind of exercise. But it is the case that if people stretch consistently over a given period of several weeks or more that there are changes in the muscles. This gets a little bit tricky in terms of nomenclature, and I just want to highlight that because I think that a number of people get frustrated and confused, in fact, when we talk about muscles getting longer. You know, that the whole concept of a muscle getting longer isn't really in keeping with reality, but there are elements within the muscles that can change their confirmation. So, to get a little bit detailed here, and we won't spend too much time on this, but I just want to acknowledge this for those of you that are interested in neuromuscular physiology and how it relates to flexibility. You know, you have your muscle fibers and then you have your so-called myofibrils. So, you can imagine kind of a single fiber, that fiber, of course, will get input from those motor neurons. And then within those fibers, you have what are called sarcomeres. And you can kind of think about sarcomeres as little segments, kind of like the segments of bamboo. If you ever look at bamboo, it's not just one big stalk, it's got those little outpouching along the way that going to break up the what would be just one big stalk of bamboo into different segments, but they're all connected. The sarcomeres are somewhat like that. And within the sarcomeres you have a couple of different components. One thing is called myosin, which is like a thick layer, and then the other is actin. And those are interdigitated, as we say, they're kind of connected to one another, kind of like if you were put your fingers together from your two hands. If you put your fingers in between one another, that's interdigitated, literally interdigitated in this case, so pun intended. And that myosin and actin kind of move relative to one another and they have a lot to do with your ability to contract muscles. When we stretch muscles, when we go through a stretching practice, there are a number of things that change, some neural, some related directly to connective tissue, but also it appears from really nice work mainly done from McGill University, I'll provide a link to a couple of these studies if you want to dig in there more deeply, that change the confirmation, the relative size and spacing of some of these things like sarcomeres and the way that myosin and actin kind of work together. But we don't want to think of muscles as lengthening, we can, however, think about the resting state of a muscle being slightly different or, indeed, very different than the resting state of a muscle of somebody or of a limb that has not undergone regular flexibility training. So, that's as much time as I want to spend on that because we could spend an entire hour getting right down into the details, but I do want to emphasize, however, that muscles have different parts, they have fibers, they have sarcomeres, they have myosin, they have actin. But the idea of making our muscles longer, that reflects a number of processes that occur basically within an existing muscle length. The length of our muscle bellies and where our insertions are relative to our connective tissue in our limbs is genetically determined, right? Some people have, for instance, a bicep that goes all the way from the crook of their elbow up to their shoulder, right? And some people can if they were to put their arm in a 90 degree angle could put two or three fingers between their bicep and their elbow. They have, we can say, a shorter bicep, relatively shorter. Now, the reason I mentioned these highly detailed cellular mechanisms is because as we start to embark on different protocols for using stretching to increase flexibility and range of motion, we need to ask ourselves what is preventing our ability to extend range of motion? Is it the spindle, right? Is it because the muscle is stretching too much? Oftentimes, it can be because of that and/or because of a sense of pain or simply a sense that the muscle is not in a position that it's been in before that's unrelated to pain or to spindle activation. And oftentimes, it can be related directly to these changes in the confirmation of myosin and actin, and within the context of the sarcomeres. Now, of course, you can't peer into or sense your individual sarcomeres, however, you do have neurons that innovate these areas and that send that sensory information back into the spinal cord and up to your brain to interpret. So, you'll find that as we move along, there are specific adjustments that you can make at both the macro level, meaning how much movement to insert into your stretching, right? Is it going to be a static, or a dynamic, or even a ballistic stretch? Or, for instance, at the micro level, that even just a slight sub-millimeter or millimeter increase in the stretching of a given muscle

00:47:16 Tool: Protocol - Antagonistic Muscles, Pushing vs. Pulling Exercises

and it related tissues can translate into an increased range of motion performance. As a quick but relevant aside, I thought I'd share with you something useful that's also grounded in this notion of antagonistic muscles. So, for those of you that do resistance training, whether or not it's with body weight, or with physical weights, or machines, what have you, you may have found that if you, let's say, were to do three sets of a pushing exercise, so this could be pushups, this could be bench presses, this could be shoulder presses, something of that sort. And then, later in the workout you were to do, let's say, machine pull-downs, or pull-ups, or chin-ups of some sort, so a pulling exercise. Typically, what you would find is if you were to do what's often called straight sets, so you would do three sets of pushups, let's say, with two minutes of rest in between that you might be able to get a certain number of repetitions on the first set. Let's just for sake of example, let's say you can get 10 repetitions on the first set, and then you get eight repetitions on the second set, and then you get six repetitions on the third set with two minutes in between, and then you would move on at some point to your pulling exercises. And similarly, let's say you were doing chin-ups or pull-downs and you would get 10 repetitions, rest two minutes, eight repetitions, rest two minutes, and six repetitions. Okay, fine. Well, typically what people discover is that if they interleave their pushing and pulling exercises, provided they do that for muscles that are antagonistic to one another. So, in this case, pushing with the chest, shoulders, and triceps for the pushing exercises, and pulling with the back and biceps, and, of course, there are other muscles involved as well. But because those muscle groups are at least in part antagonistic to one another, what people often find is that if they were to, say, do their pushing set, get 10 repetitions, then move to a pulling set after just say 60 seconds and perform that pulling set, then go back to the pushing set, then go back to a pulling set, push, pull, push, pull, in other words, interleaving their sets. Even if they were to maintain the same amount of rest between sets of pushing and sets of pulling, what they discover often is that the drop in the number of repetitions that they get is somewhat offset. So, rather than get 10, 8, 6, as it were with the straight sets, it will be 10, 9, 8. So, what this means is not that you're increasing the total rest time to four minutes between sets because then, of course, it wouldn't be equivalent, but rather that while maintaining the same amount of rest between sets for this same muscle group, by going from push, pull, push, pull of antagonistic muscles, you're able to have improved performance. And the reason for that has everything to do with what we were describing before, which is that typically if you were to do push set, rest, push set, rest, push set, rest. Well, in between those sets and, in fact, actually during those sets of pushing, the pulling muscles that would be involved in the chin-ups or pull-downs, et cetera, are actually relaxing, or at least are being released of some tension, including the activation of the spindles among other things. So, that's a long-winded way of saying that interleaving push and pull of antagonistic sets can leverage some of the same neural circuits that we're talking about leveraging for sake of increasing flexibility. Now, I offer this to you as a tool that you can try. One of the challenges with using this tool, however, is that you often have to occupy multiple sites within the gym. You know, if you're doing this at home and you have your own gym, that's one thing. If you're doing this in a gym where you have multiple pieces of equipment, well, then you become that person who has essentially taken over some small corner, or multiple corners, or machines within the gym. And oftentimes, you'll find that you'll walk back to a machine or you'll walk back to a given resistance exercise and someone has now taken it over and the whole thing could be thrown off. So, it takes a little bit of orchestrating in order to do properly. But in general, what people find is that this can allow you to enhance performance overall of these individual movements, again, while maintaining the same amount of rest. And even if you choose not to do this, I encourage you to pay attention to this as a concept because, again, it's leveraging this idea of antagonistic muscles, flexors and extensors, antagonistic neural relationships between the spinal cord mechanisms that control one set of muscles and activating those muscles,

00:51:57 Types of Stretching: Dynamic, Ballistic, Static & PNF (Proprioceptive Neuromuscular Facilitation)

allowing the opposite antagonistic muscle to relax and therefore to perform better on its next set. So, now I'd like to shift to the question of what types of stretching can and should we do to increase limb range of motion? If our goal is to do that in the most efficient way possible 'cause I realize that most people don't have endless amounts of time to dedicate to a stretching practice. And even for those of us that do, I'm sure that you want to get the most outcome for a given effort. And what are the modes of stretching that are going to allow us to increase our flexibility and limb range of motion most safely? Now, there are a number of different types of stretching or methods of stretching. Broadly defined, we can describe these as dynamic, ballistic, static, and what's called PNF stretching. PNF stands for Proprioceptive Neuromuscular Facilitation, and it involves and leverages many of the mechanisms that I described to you earlier. The first two that I mentioned, dynamic and ballistic stretching, both involves some degree of momentum, and can be distinguished from static and PNF-type stretching. Now, to distinguish dynamic stretching from ballistic stretching, I'd like to focus on this element of momentum. Both involve moving a limb through a given range of motion, in dynamic stretching, however, it tends to be more controlled, less use of momentum, especially towards the end range of motion. Whereas in ballistic stretching, there tends to be a bit more swinging of the limb or use of momentum. So, I invite you to visualize what dynamic and ballistic stretching might look like in your mind, you can even try it if it's safe for you to try it. You know, you could imagine swinging your arm up overhead as much as possible and bringing it down. I'm doing this because I'm seated, it's kind of a ridiculous movement to do while seated or perhaps at all. But for instance, you can see dynamic and ballistic stretching. Anytime someone, for instance, is holding onto something with one arm or maybe not holding on and swinging out their foot, so essentially getting movement about the hip joint. And you'll notice that some people raise it up, and pause it, and bring it down, that's one form of dynamic stretching. Whereas others will swing it up and sort of let it carry itself a bit further due to the momentum at the top of the movement, and then just let it drop back down or maybe even control the descent. There is an enormous range of parameter space here or variables that one could imagine, and there's just simply no way that we could subdivide all those. But again, dynamic and ballistic stretching both involve movement, so we have to generate some force in order to create that movement. Ballistic stretching involving a bit more momentum or sometimes a lot more momentum, especially at the end range of of motion. Now, both of those are highly distinct from static stretching, which involves holding the end range of motion, so minimizing the amount of momentum that's used. So, to stay with the simple example that we are all now familiar with from our earlier discussion, slowly bending over at the waist and trying to touch your toes or putting your hands to the floor and then holding that end position before coming up in a slow and controlled way, such that you reduce the amount of momentum to near zero would be one example of static stretching. Static stretching can be further subdivided into active or passive. Right, there are different names for these kinds of approaches. You can hear about the Anderson approach or the Jander approach, you can look these sorts of things up online. And, again, people tend to name things after themselves, so some of these are proprietary related to specific programs, I'm not focusing on those. Others come to be named after the physiologists or the practitioners that initially popularize them. As is always the case, there's always a naming and renaming and claiming of territory with these things. For the time being, I'd like to just emphasize that static stretching can be both active, where there's a dedicated effort on the part of the stretcher, you, to put force behind the hold to kind of extend or literally to extend the range of motion. And then, there's also passive static stretching in which it's more of a relaxation into a further range of motion, and that can be a subtle distinction. And there are other ways in which we can further distinguish active and passive static stretching. But nonetheless, static stretching involves both those types of elements, active and passive, but is really about eliminating momentum. And then, there's the PNF, the Proprioceptive Neuromuscular Facilitation. And proprioception has several different meanings in the context of neuroscience and physiology. To just keep it really simple for today, proprioception involves both a knowledge and understanding of where our limbs are in space and relative to our body. Typically, relative to the midline, so the brain is often trying to figure out where are our limbs relative to our midline down the center of our body. And we know where our limbs are based on so-called proprioceptive feedback, so that's feedback that comes from sensory neurons. Right, now you know what sensory neurons that are essentially monitoring or responding to events within the joints, the connective tissue, and the muscles, and within the deep components of the muscles like the spindle reflex, and within the tendons like the GTO, the Golgi tendon organ. So, PNF-type stretching leverages these sorts of mechanisms, these neural circuits, by way of, for instance, you would lie on your back and if your goal is to increase your hamstring flexibility and the flexibility and range of motion of other related muscle systems, you might put a strap around your ankle and pull that muscle. Or I should say, excuse me, that limb towards you, you're not going to pull the muscle towards you, you're going to pull that limb your ankle towards you to try and get it sort of back over your head. And then, progressively relaxing into that, or maybe even putting some additional force to push the end range of motion and then relaxing it. And then, actually trying to stretch that same limb or increase the limb range of motion without the strap. Right, sometimes these are assisted by other people. So, people will even use loads, sometimes they'll even use machines. There are a number of different apparati that have been designed for this, sometimes it'll involve a training partner. There's a huge range of PNF protocols, and those protocols can be done both by oneself with or without straps, with machines, with actual weights, or with training partners. If you're interested in the variation of exercises to, say, target your hamstrings versus your quadriceps versus your shoulders versus your chest muscles, et cetera, your neck muscles, and so on, there is an enormous range of information on dynamic, ballistic, static, and PNF stretches for all the various muscle groups. And I should say there are some excellent books on those topics, there are also some excellent videos on YouTube and elsewhere. Nowadays, it's pretty easy to find exercises that allow you to target specific muscle groups. Again, I encourage you to be safe in how you approach this, and I would encourage you also to pay attention to the information that soon follows as to what sorts of protocols one would use to apply those exercises. But the number of exercises and the availability of those exercises for targeting different muscle groups with these four different kinds of stretching is both immense and fortunately, thankfully, immediately accessible to all of us often at zero cost.

00:59:36 Tool: Increasing Range of Motion, Static Stretching Protocol, Duration

So, specific exercises to target specific muscle groups aside, we've now established that there are four major categories of stretching, or at least those are the four major categories I'm defining today. And we can further divide those categories into which are the ones that are going to be most effective for increasing range of motion in the long-term, not just in one individual session. And there have been a number of studies exploring this. I can list out at least four, and we'll put those four as a kind of a cluster under one heading in the show note captions that arrive at essentially the same answer, which is that for increasing limb range of motion, it does appear that static type, including PNF, but static-type stretching is going to be more effective than dynamic and ballistic stretching. So, at least in my mind, this is good news. Why is it good news to me? Well, while dynamic and ballistic stretching can be immensely useful for improving performance of specific movements, in particular, in the context of particular sports like tennis, or in sprinting, or frankly for any sport, they do carry with them a certain amount of risk because of the use of momentum. So, you don't need to be highly trained in order to perform them. In fact, there is a place and we will describe when one would want to apply dynamic or ballistic stretching. I'll just give away for now, I think that most physios out there and certainly the ones that I spoke to, Dr. Andy Galpin, Dr. Kelly Starrett, and a few others point to the fact that doing some safe dynamic and ballistic stretching prior to, say, a resistance training session, or maybe even prior to a cardiovascular training session can be useful both in terms of range of motion effects and in terms of neural activation effects. I don't want to use the words warm-up because warming up is typically associated with increasing core body temperature, as it should be, but for engaging the neural circuits and becoming familiarized with the neural circuits that you're about to use in other movements while also increasing the range of motion of the joints involved in those movements so that you can perform them more safely and more confidently. So, I'm certainly not saying, I want to repeat, I'm certainly not saying that dynamic and ballistic stretching are not useful, they absolutely are, but in terms of increasing limb range of motion in the long-term of truly becoming more flexible as opposed to transiently more flexible, static stretching, which includes PNF, appears to be the best route to go. So, if your goal is to increase your limb range of motion for a given muscle group, or perhaps for all muscle groups, although you can imagine that'd be pretty tough. I mean, you're not going to spend time, I could imagine, working on your tongue muscle control or neck muscle control and every muscle control, but most of us want to reduce so-called tightness in air quotes and increase limb range of motion for certain muscle groups. And it appears that the best way to do that is going to be static stretching of some kind, which raises the question of how often to do that static stretching and how long to hold those static stretches. And we can also ask the question, we should ask the question, where to hold those static stretches? Is it always a good idea to hold those static stretches at the end or the point of maximal range of motion? We're going to address that now. There's some terrific science around this. A slightly older study, but nonetheless a powerful one because it provided a foundation for a lot of subsequent work, which basically served to just confirm the answer they got here is a study from Bandy et al. And the title of this study is The Effect of Time and Frequency of Static Stretching on the Flexibility of the Hamstring Muscles. It was a study involving 93 subjects, so 61 men, 32 women ranging an age from 21-39 years, so a pretty broad demographic who had limited hamstring muscle flexibility, here I'm paraphrasing, and randomly assigned to one of five groups. So, the four stretching groups stretched five days per week for six weeks, the fifth group, which served as a control, did not stretch. The results clearly show that quote, "The change in flexibility appeared to be dependent on the duration and frequency of stretching." This is great, this tells us that stretching for a given amount of time scales with the amount of limb range of motion improvement that one will see. There were many interesting findings within this study, but the one that I'd like to highlight most is quote, "The results of this study suggest that a 30 second duration is an effective amount of time to sustain a hamstring muscle stretch in order to increase range of motion. No increase in flexibility occurred when the duration of stretching was increased from 30 seconds to 60 seconds, or when the frequency of stretching was increased from one to three times per day." Okay, so now we're starting to lay down some parameters. What this study reveals and what subsequent studies tell us, and we will get into those subsequent studies, is that ideally one would do static stretches that are held for 30 seconds. Perhaps more in certain instances, and I'll explain when that can be useful, but here holding those stretches for more than 30 seconds did not turn out to be additionally useful. So, if you're going to stretch your quadricep, for instance, and you're going to hold that stretch in static fashion, remember not using momentum, and you can use the mental tricks of either trying to push through the pain, which I don't recommend necessarily, I think that makes us prone to injury, or to relax into the stretch, but nonetheless providing some force typically with a hand in order to pull your ankle back, if you're doing a quadricep stretch, some people might do this on the edge of a sofa. Remember, there are a lot of different exercises and ways to do this that you can explore elsewhere. Well, holding that static stretch for 30 seconds appears to be sufficient to stimulate an increase in limb range of motion over time. Again, these are protocols that were used repeatedly over time, and we'll talk about how often to repeat them in order to get maximal effect. But 30-second holds for static stretches

01:05:56 Tool: Static Stretching Protocol & Frequency

is the number that I think we want to focus on and that most of us are going to want to utilize. So, now let's explore how many sets of static stretching one ought to do in order to get a maximum range of motion improvement while not placing us into a system that's going to create injury nor a situation where we have to be constantly stretching throughout the day because, again, most of us don't have time to do that. This issue of sets is an important one. In the context of cardiovascular exercise, we've talked about the data that support the fact that doing at least 150 and ideally as much as 200 minutes per week of Zone 2 cardiovascular exercise is very useful for cardiovascular health and for other aspects of health. And, of course, there are other aspects of cardiovascular exercise that could be layered onto and into that that can be useful like 90 second maximal sprints, et cetera. Discussed this a lot in the episode with Dr. Andy Galpin and on our episode about endurance. And we also talked about sets in the context of strength and hypertrophy building, building muscle size and/or strength in the episode about that. And in particular, in the episode with Dr. Andy Galpin, and there, we could also arrive at some specific parameters. And it's going to vary, of course, between individuals, depending on how hard you train, whether or not you take sets to failure, your repetition range, et cetera, but in the context of strength and hypertrophy building, we arrived at a approximately six, maybe as many as 10 sets per week per muscle group. Some of that work is done as direct work to a given muscle group, some of that work is indirect. So, doing certain pulling exercise, of course, will target the latissimus dorsi muscles, but also the biceps. So, that doesn't necessarily mean you have to do 10 sets for the biceps and for the lats, sometimes you're getting some indirect work, et cetera. All of that was delineated in the episode with Dr. Andy Galpin. And we arrived at those numbers of sets according to the same criteria that we will apply here, what is the minimum number of sets both to maintain and to improve a given mode of performance? Strength and hypertrophy or cardiovascular health, again, to either maintain or improve. And we can do the same thing for improving or maintaining range of motion because as I mentioned earlier, the data pointed to the fact that if we don't do some dedicated work to improve range of motion over time, we will lose our flexibility and limb range of motion over time just by virtue of the fact that we're not doing anything to offset that. So, whether or not you want to maintain, reestablish, or gain limb range of motion, static stretching of holds of 30 seconds appear to be best. Now, the question is how long should you do that? And how many sets should you do that? And how many times a week should you do that? And to answer those questions, I'm going to turn to what I think is a really spectacular review. This was a review that was published in the year 2018, so it's fairly recent, first author Thomas, Ewan Thomas, last author Palma. We will put a link to this in the show note caption. The title of the paper is The Relation Between Stretching Typology and Stretching Duration: The Effects on Range of Motion. It's a very straightforward title. This is a review article that explored a number of different studies, had criteria for whether or not those studies could be evaluated in the context of the questions here, had some quality standards and some other standards that they applied. And basically, windowed down a large collection of studies to a remaining 23 articles that were able to be considered quote, "Eligible and included in the quantitative synthesis done here." So, key points from that quantification and synthesis done in this paper. First of all, and I quote, "All stretching typologies showed range of motion improvements over a long-term period. However, the static protocols showed significant gains with a p-value less than .05," which means a probability that cannot be explained by chance alone, "When compared to ballistic or PNF protocols." So, again, that we're hearing is that static stretching is the preferred mode for increasing limb range of motion. Although, here they make the additional point that static stretching might even be superior, not just to ballistic stretching, but also to PNF protocols. Because before, as you may recall, there was a distinction between ballistic and dynamic, and static and PNF. And so, here it appears again that static stretching is sort of rising to the top of the list as the optimal approach relative to all other stretching approaches, at least in the context of increasing limb range of motion. The authors go on to say, "Time spent stretching per week seems fundamental to elicit range of movement improvements when stretches are applied for at least or more than five minutes per week." Okay, this is critical. This is not five minutes per stretch. Remember, 30 seconds per static stretch, but at least five minutes per week. Whereas the time spent stretching within a single session does not seem to have a significant effect for range of motion gains. If this is getting confusing, I'll make sure that you soon understand exactly what we can export from these conclusions. The data indicated that performing stretching at least five days a week. Now, some of you may already be groaning, for at least five minutes per week. Okay, so five days per week, that's a lot, but at least five minutes per week, five minutes per week is not that much. "Using static stretching may be beneficial to promote range of motion improvements." Okay, I've read this study in detail now, they highlight, again, the reduction in flexibility that occurs from 20-49 years of age and so on, how acute bouts of short-term stretching up to three weeks can improve stretch tolerance. I think that's a key point that in the short-term, the first three weeks of embarking on a stretching and flexibility program, much of the improvements come from the short-term neural improvements that we talked about before of inhibiting the spindle reflex and so on. And also, a stretch tolerance, a comfort with doing the movements and maybe even a comfort in overriding some of the pain mechanisms. I'll talk a little bit more about that in just a bit and the particular utility of yoga. Something that I don't often practice, but that after reading this article that I'll mention in a little bit, I'm considering perhaps taking up some form of yoga protocol. Now, I've already highlighted some of the key take aways from the study, namely that we need to get at least five minutes per week of static stretching per muscle group. And based on the previous paper that we talked about, we need to divide that five minutes into sets of 30 seconds each. And as I mentioned earlier, it doesn't seem to be the case that you can do all of that in one day, unfortunately. It does seem important that the frequency of stretching practice distributed throughout the week is important. So, let's talk protocols. We are now talking about doing static stretching, so holding, so limiting momentum and holding a stretch for 30 seconds per set. We're talking about trying to achieve five minutes per week of those static holds, but that we can't do it all in one session because the frequency of sessions distributed throughout the week correlates with the improvements in limb range of motion. So, what this means is that we should probably be doing anywhere from two to four sets of 30 second static holds stretches five days per week or some variant thereof. And I do say some variant thereof because it turns out that even though there was that earlier study that we talked about that holding a stretch for more than 30 seconds, in that case 60 seconds, didn't turn out to be additionally beneficial. It appears that if you do hold those stretches for 60 seconds per static stretching set, for instance,

01:13:55 Tool: Effective Stretching Protocol

you can get away with stretching fewer days per week overall. So, in order to make this as clear as possible 'cause I do realize there are a lot of parameters and you might be asking, "Why didn't you just make me a list of the exact things I should do?" Well, it doesn't work that way because once you understand the mechanisms and once you understand your particular goals, this information is designed for you to be able to construct a stretching program that is tailored to your specific goals. If I just gave you the stretching program that I'm doing, or I should say that I'm soon to be doing 'cause I'm soon to be doing one based on the research for this particular episode. Well, that wouldn't be beneficial for you because, for instance, if you have very flexible hamstrings, but not very flexible quadriceps, or you are somebody who is engaged in sport or not engaged in sport, what you need to do is going to vary somewhat. So, what would effective stretching protocol look like? We're all trying to improve limb range of motion for different limbs and different muscle groups. But just by way of example, and it's because the one we've been using, let's talk about hamstrings for the time being. This could, of course, be applied to other muscle groups. Let's say you want to improve hamstring flexibility and limb range of motion about and around the hamstring and involving the hamstring, you would want to do three sets of static stretching for the hamstring. Again, easy to find such exercises on the internet. You would do that by holding the stretch for 30 seconds, resting some period of time, and doing it again, holding for 30 seconds, resting some period of time, and then holding it for 30 seconds. That would be one training session for the hamstrings. I have to imagine that you'd probably want to stretch other muscle groups as well in that same session. Although, at least as far as I could tell, there was no data pointing to the fact that you couldn't do your hamstring stretching one part of the day and your quadricep stretching another part of the day. But presumably, you're going to want to combine your flexibility training into one single session. So, three sets of 30 seconds each get 90 seconds, and you would do that ideally five times a week or maybe even more because it does seem like frequency distributed throughout the week is an important parameter. Now, one thing that we have not highlighted or at least described is how long to rest between stretching sets. And despite my efforts, I could not find research-backed information that pointed to whether or not 30 seconds of rest for every 30 seconds stretching, or 60 seconds rest for every 30 second stretching was ideal. I think it's reasonable to assume that doubling the amount of time for the interleaving rest would be appropriate or at least doable. If anyone out there has knowledge about rest between stretching sets and has some physiology, or some biology, or some experiential information as to why a given ratio of duration of static stretch to rest in between static stretch sets ought to be used, please put it in the comments on YouTube, that'd be a terrific way for us to get that information. I'd love to do any follow-up to links that you provide and so on. But now, we're starting to build into a protocol that is backed by the scientific data.

01:17:12 Tool: Warming Up & Stretching

Three sets of 30 seconds of holds done five times or maybe even six times per week. One thing that did show up in my exploration of the peer-reviewed research is this notion of warming up for all this. We haven't talked about that yet. In general, to avoid injury, it's a good idea to raise your core body temperature a bit before doing these kinds of stretches. Even these static stretches, which we can sort of ease into and don't involve ballistic movement by definition. And the basic take away that I was able to find was that if we are already warm from running, or from weight training, or from some other activity that doing the static stretching practice at the end of that weight training, or cardiovascular, or other physical session would allow us to go immediately into the stretching session because we're already warm, so to speak. Otherwise, raising one's core body temperature by a bit by doing five to seven, maybe even 10 minutes of easy cardiovascular exercise or calisthenic movements, provided you can do those without getting injured, seems to be an ideal way to warm up the body for stretching. We should be warm or warm-up to stretch, although those warm-ups don't have to be extremely extensive. And then, just by way of logic, doing the static stretching after resistance training or cardiovascular training seems to be most beneficial. In fact, and unfortunately we don't have time to go into this in too much detail today, I was able to find a number of papers that make the argument that static stretching prior to cardiovascular training and maybe even prior to resistance training can limit our performance in running and resistance training. I realize that's a controversial area, you have those who say, "No, it's immensely beneficial," you have those who say, "No, it inhibits performance," and those that say, "No, it's a matter of how exactly you perform that static stretching, and which muscle groups, and how you're doing this, and how much time in between static stretching and performance." But to leave all that aside, doing static stretching after some other form of exercise and if not after some form of exercise,

01:19:17 Limb Range of Motion & General Health Benefits

after a brief warm-up to raise your core body temperature definitely seems like the right way to go. Now, for some of you out there, and I confess for me as well, doing something five days a week seems like a big commitment, even if that commitment is one to only do three sets of 30 second static stretches. I say this because you've got the warm-up, I generally like to bring a kind of a focus and dedication to a practice. And, of course, because when doing these kinds of protocols, it's likely that you're not just stretching your hamstring, so it's not just 90 seconds of work with a minute of rest in between, but very likely that we're also doing quadricep stretching, and also doing stretching for the shoulders, and stretching for the back, and the neck, and so on. And so, that entire session is going to take some time, and five days a week is a pretty serious commitment for most, especially for those of us that don't exercise or do athletics for a living, which I don't. So, there is some evidence from the literature that one can get away with, or I don't even know that we should think about it as getting away with, but that one can do longer hold static stretches of up to say 60 seconds, but do fewer total sessions per week. So, rather than three 30 second static holds, doing three 60 second static holds and doing those every other day. And there really hasn't been a systematic exploration of this. The article that I was referring to just a few moments ago, this analysis of the 23 articles was combined into this enormous set of tables and some really quite nice graphs that you're welcome to look at since we're going to provide a link to the study. There are a couple of key take aways that I want to mention that are separate from this issue of how long to stretch and how often. First of all, they describe in their discussion that there were improvements in range of motion independent of whether or not people did static stretching, active stretching, passive stretching, ballistic stretching, or PNF stretching. So, all of those forms of stretching will improve limb range of motion. This is essential to point out and I want to emphasize this. Static stretching, however, gave the greatest degree of gains in limb range of motion. And on average, they saw a 20.9% increase, but some of the other increases they observed were also quite substantial. So, ballistic stretching can also provide some pretty impressive limb range of motion improvements. However, they tended to be in the range of, here they point out, 11.65% increase, or in the case of PNF, a 15% increase. So, it appears that the greatest improvements in limb range of motion for your time spent and effort spent is going to be this minimum of five minutes per week to elicit a significant response with five days being the minimum weekly recommended frequency to achieve significant range of motion improvements. I confess, this was pretty surprising to me when I compare flexibility training to, say, resistance training for strength and hypertrophy. I've had the experience, and I know that other people have had the experience, and I think Dr. Andy Galpin would probably agree that provided one trains hard enough and appropriately that you don't need to train resistance training five days a week in order to get significant improvements in strength and hypertrophy. Some people might need to, but you can get a lot of positive results in those variables with less frequent training, certainly with three or four days a week of training. And for cardiovascular training, I'm not aware of anyone having tested whether or not one very long run each week can actually increase cardiovascular fitness and you're not doing anything else. Although, I have to imagine you'd probably see some improvement compared to not doing anything, but most people are doing repeated training sessions of cardiovascular strength training. Not a lot of people are doing five days a week of strength training, at least that I'm aware of. Some people are, but most people I think are not. And some people are doing five or more days a week of cardiovascular training. I'm guessing that most people are not doing five days a week of dedicated static stretch range of motion directed training, but it does appear that that frequency about the week getting those repeated sessions, even if they are short for an individual muscle group, turns out to be important. And so, that points to perhaps the reason why so few people are doing dedicated range of motion work, but it also reminds me that all of the studies that were described at least in this review and some of the other ones that were not really show impressive changes in limb range of motion. I mean, 20+%, or even 15% with PNF, I mean, these are big changes that are going to benefit us, they're going to offset the age-related losses in flexibility, for sure, if one is dedicated about these practices. And in many cases, they're going to increase limb range of motion in ways that are going to allow us better performance in certain physical endeavors, certainly better balance. All right, we haven't really talked about balance and stability, but range of motion can impair balance and stability in some extreme circumstances, but by and large, limb range of motion, lack of tightness, improved posture, improved physical performance, excuse me. And things of that sort is something that I think we can all benefit from, and that are key features of longevity. We don't often think of them because we so prioritize cardiovascular health and the relationship between the heart and brain health, and resistance training, and musculoskeletal hypertrophy, or strength, et cetera. But as I delved into this literature, it really highlighted for me the extent to which having really good limb range of motion, at least maintaining limb range of motion as we age from year to year, and maybe even improving limb range of motion can be immensely beneficial for reducing pain for, again, improving posture, improving our ability to perform, to walk, et cetera. And indeed, there's a whole literature that relates our limb range of motion to things like pain management of things related to headache and so on and so forth. So, limb range of motion is not just about becoming a contortionist or being able to complete the yoga class,

01:25:30 PNF Stretching, Golgi Tendon Organs & Autogenic Inhibition

it really is about maintaining the integrity and the health of the neuromuscular system, the connective tissue, and the neuromuscular connective network because those are indeed working as an ecosystem and a network. I'd like to just briefly touch on PNF stretching for a moment. Again, this is a vast landscape with many parameters and different practitioners, a lot of competing opinions out there, to put it lightly. Nonetheless, I do want to emphasize that the PNF training leverages those spindle mechanisms and GTO mechanisms that we talked about earlier, but I realize that in describing the quadricep contraction, hamstring stretch little mini-experiment that hopefully you did, that I didn't really highlight the role of the GTOs, the Golgi tendon organs that much. And I just would like to just briefly do that for a moment. The GTOs have multiple functions. In fact, I think even though GTOs are in every medical textbook, every physiology textbook, every first year neuroscientist learns about them when learning about the neuromuscular junctions and the mechanisms of interoception, et cetera, they're likely to have other functions as well. And one of the reasons why PNF stretching does work, whether or not you're doing that by using a strap to pull back a limb, or whether or not you're actively contracting your quadriceps to then release and emphasize stretch range of motion for your hamstrings and related muscle groups is that activation of those GTOs, meaning putting loads and tension into that system can inhibit the spindles in the opposite antagonistic muscle groups. Okay, so one of the reasons why flexing, or I should say contracting your quadriceps really intensely for some period of time allows your hamstrings to subsequently experience greater range of motion. And again, it's not just the hamstrings, but the related connective tissue and neural circuits, et cetera is because yes, it's quote-unquote relaxing the hamstrings and the spindle, but there's also a direct relationship between activation of the GTOs in the quadricep and release of the spindles in the hamstring and related muscles. This has a name, it's called autogenic inhibition, it's a fancy name for contraction of one muscle group providing a relaxation of the other muscle group that's antagonistic to it. And it relates back to this idea of interleaving sets in the gym. So, if you think back to that example, now it should make sense as to why, for instance, if you do, let's say, a set of bench presses or shoulder presses, and you let's say you get 10 repetitions and you fail on the 11th, that muscle is very, very fatigued. If you were to rest some period of time and then go back and do another set, well, during the rest, that muscle group has been relaxing, it's obviously not contracting the same way it was during the resistance set, but by going and doing a pulling exercise that involves the antagonistic muscle group, so strongly contracting the back muscles through a pull like a pull-down, or a chin-up, or a row-type exercise, you're activating or near activating the GTO system in those pulling muscles in a way that provides autogenic inhibition for the pushing muscles. Now, again, the physios out there are probably either screaming or banging their heads against whatever sound system this happens to be arriving through to them saying, "Wait, but in many cases, the GTOs aren't activated enough to provide that autogenic inhibition." That's true, but even the sub-threshold activation of those intraspinal circuits, so the place where the GTO circuit and the spindle circuit interact, can provide an additional replenishment of, say, the pushing muscles while you're activating those pulling muscles. And this is at least one, not the only, but at least one mechanism by which interleaving push and pull, push and pull for both strength and hypertrophy training, but also for range of motion stretching-type training can allow you to achieve better results in a shorter period of time. And I raise this because I want to keep in mind the efficiency of any training program. We just a moment ago established that doing, for example, three sets of 30 second static holds can be very useful for the hamstrings with let's just say for sake of simplicity and practicality a minute's rest in between. But during that minute's rest, you can stretch the opposite antagonistic muscle group, such as the quadriceps, or if you want to use PNF training, you could do loading of the quadriceps in between. So, there are a number of different ways in which you can start to interleave static stretching with PNF stretching, you can start to interleave even PNF-type protocols with resistance training, although that gets a bit more complicated. You can really start to construct and build protocols that are ideal for you. What we will do is for an upcoming Neural Network Newsletter. So, for those of you that aren't familiar, the Huberman Lab Podcast has a so-called Neural Network Newsletter, these are monthly newsletters where we put distilled points from the podcast and oftentimes protocols in a downloadable PDF form. You can access it by giving us your email, we don't share your email with anybody. If you want to see examples of these, you can go to hubermanlab.com and go to the menu and see Newsletter, you don't have to sign up for anything to see examples of what these are like. I'll provide a couple of different protocols, one that is pure static stretching, one that involves PNF-type stretching, and I'll also put down a protocol that involves the antagonistic interleaved muscle training of the sort that I've been describing a few times throughout this episode. And then, you can try and apply those

01:31:23 Tool: Anderson Protocol & End Range of Motion, Feeling the Stretch

either separately or maybe combine them in some way that's useful for your goals. There are a couple of key elements that are essential for building a safe and effective range of motion increasing program that arrived to us both through the peer-reviewed research and, admittedly, from people that have been involved in teaching and training range of motion for a very long period of time. Some of you may be familiar with the so-called Anderson method, it's been around for a long time. Actually have never met Anderson, I don't, I should know this, I don't even know if he's still alive, I hope he's still alive, but in any event, there are a lot of different features to the Anderson and other protocols. But one of the aspects of the Anderson protocol that I think is highly relevant. In fact, I know is relevant to the peer-reviewed research that we're going to talk about in a few moments is this notion of pushing through pain, and how active or how passive to be about static stretching. Now, this is somewhat subjective. Right, if you think about getting into a stretch, again, we'll just use the hamstrings for example. So, you're either reaching for your toes while seated, or maybe you're using a strap and you're raising your foot overhead while lying down, or maybe you're doing a toe touch-type exercise. How far should you reach? Where is the end range of motion? Should you balance? Should you not balance? We're going to talk a little bit more about that in a moment, but Anderson has an interesting idea and principle, which has thread through a lot of his teachings

01:32:50 Tool: Effectiveness, Low Intensity Stretching, “Micro-Stretching”

that I think are very much in keeping with the study that I'm about to describe next, where he emphasizes to yes, to stretch to the end of the range of motion, but not to focus so much on where that range of motion happens to be that day. So, for instance, not thinking, "Oh, I can always touch my toes, for instance. And therefore that's the starting place for my flexibility training today." But rather to take the entirety of your system into account each day and understand that, okay, provided your warmed up appropriately, that you're now going to stretch your hamstrings, for instance, and you're going to reach down for your toes, but that your range of motion might be adjusted that day by way of tension and stress, or by way of ambient temperature in the room. And to basically define the end range of motion as the place where you can feel the stretch in the relevant muscle groups. I think this is important because unlike resistance training or cardiovascular training, where we can measure distance traveled over time in the case of cardiovascular training, or how much weight is on the bar, and count repetitions, et cetera. With range of motion training, of course, range of motion is the feature that we're interested in, but there is likely to be a lot of variation from day-to-day based on a number of different internal and external factors. And so, the Anderson method is really about getting into static and other forms of stretching. I think today we've mainly been focusing on static stretching and holding the end range of motion, but really paying attention to the feel of the stretch and the muscles involved. And there are parallels in resistance and cardiovascular training too I realize, right? In the case of trying to build hypertrophy, or I should say improve hypertrophy, muscle size, oftentimes the best advice that one can give is to don't try to lift weights, but rather to challenge muscles. Now, of course, you need to provide adequate loads in order to get hypertrophy, but when you're training purely for strength, it's about moving weights. When you're training purely for hypertrophy or mainly for hypertrophy, it's really about challenging muscles using weights or other forms of resistance. And similarly, and in keeping with this Anderson method, when trying to build limb range of motion, doing static stretching at a place where it's difficult, but that you can experience the stretch of the muscle cognitively, consciously being able to focus on the muscles and their stretch is at least as useful as is evaluating the current range of motion you're able to achieve. So, what does this mean? This means feel the muscles as you stretch them, don't just go through the motions. And this means don't get so attached to being able to always achieve, for instance, a stretch of a given distance within a given session. You might actually find that by just finding the place where you can't get much further and holding the static stretch there, that on the second and third set that you happen to be doing that day, that your range of motion will be increased considerably. Maybe not, but very likely yes, you will. And, of course, evaluating range of motion over time is the key parameter because that's the goal of all this type of work. Now, along these lines, there is this variable that we've mentioned a few times of passive versus active stretching, and there's this even more nebulous variable, this even more kind of subjective thing of how much effort to put into it? Should you push into the stretch? Would you even want to balance a tiny bit? Would you want to reach into that end point and try and extend it within a given set and session? And for that reason, I was excited to find this paper entitled A Comparison of Two Stretching Modalities on Lower-Limb Range of Motion Measurements in Recreational Dancers. Happens to be done in recreational dancers, it's a six-week intervention program that compared low-intensity stretching, which they call Microstretching. They used a capital M, so I don't know if that means that it's proprietary, although I didn't see evidence of a conflict of interest, but they call it Microstretching. But to be very clear, Microstretching in the case of this manuscript is low-intensity stretching. And they compared that with moderate intensity static stretching on an active and passive ranges of motion. Okay, so there are a lot of different variables are here, but I'll just highlight a few of the things that are really most relevant to us, and I'll give you the take away at the outset and then return to it at the end so that if I lose any of your attention in the next couple of minutes, at least you have that key take away. Basically, what they found was that a six-week training program using very low-intensity stretching had a greater positive effect on lower limb range of motion than did moderate-intensity static stretching. I find that incredibly interesting, so very low intensity, and we'll define what that means in a moment. Here, I'm quoting them, "The most interesting aspect of the study was the greater increase in active range of motion compared to passive range of motion by the Microstretching group." So, this relates to what we were just talking about a few moments ago as it relates to the Anderson method, which is that very low-intensity stretching, meaning effort that feels not painful and in fact might even feel easy or at least not straining to exceed a given range of motion turns out to not just be as effective, but more effective than moderate-intensity stretching. So, what is low-intensity static stretching? Well, they define this as the stretches were completed at an intensity of 30-40% where 100% equals the point of pain, right? So, 30-40% in these individuals, and again, I'm paraphrasing, induced a relaxed state within the individual and the specific muscle. And here they were holding these static stretches I should mention for one minute, not 30 seconds. Now, the control group was doing the exact same overall protocol, so daily stretching for six weeks, the same exercises, holding each set for 60 seconds, but were using an intensity of stretch of 80% where, again, 100 represents the point of pain or the point where the person would want to stop stretching. I find these data incredibly interesting for, I think, what ought to be obvious reasons. If you're going to embark on a flexibility and stretching training program, you don't need to push to the point of pain. In fact, it seems that even just approaching the point of pain is going to be less effective than operating at this 30-40% of intensity prior to reaching that pain threshold. The pain threshold being 100%. Now, of course, this is pretty subjective, but I think all of us should be able to register within ourselves, so whether a given range of motion or extending a given range of motion brings us to that threshold of pain or near pain. And according to this study at least, operating or performing stretching at an intensity that's quite low, that's very relaxing turns out to be more beneficial in increasing range of motion than is doing exercises aimed at increasing range of motion at a higher intensity. Okay, so lower intensity stretching, I should say lower intensity static stretching appears to be the most beneficial way to approach stretching. And I think that's a relief probably to many of us because it also suggests that the injury risk is going to be lower than if one were pushing into the pain zone, so to speak. The authors offer a number of different explanations as to why this approach, this Microstretching approach, might be more effective. Here, I'm paraphrasing from their discussion where they mentioned that it could be hypothesized that they had improved reciprocal inhibition within the hamstring muscle group. So, this gets right back to the sorts of neural mechanisms that we talked about before, that somehow by doing this low-intensity stretching that they were able to access some of those spindle and GTO-type mechanisms that we were referring to earlier, and the inhibition of hamstring and quadricep stretches. They also offer a number of different ideas about how this could shift the activation of the so-called sympathetic, remember the kind of stress division of our nervous system, and to reduce that relative to activation of the parasympathetic arm of the nervous system. I confess, they have a couple of arguments around sympathetic, parasympathetic that are somewhat convoluted. I will just in fairness to the neuroscience on those systems, I wouldn't suggest putting too much weight on their arguments about sympathetic and parasympathetic. To my mind, they didn't really hold much water, but here I'm not trying to be disparaging of the overall work, which I think is really quite sound, which is that low intensity, so called Microstretching,

01:41:33 Tool: Should you Stretch Before or After Other Exercises?

is going to be the most effective way to increase limb range of movement over time. I want to just briefly return to this idea of whether or not to do ballistic or static stretching before some sort of skill training, or weight training, or any kind of sport, or even cardiovascular exercise like running. Again, the data are really split out there. There are even folks who suggest that doing any kind of stretching prior to running is going to lower running efficiency, it's going to require essentially more work and more oxygen uptake at a given speed for a variety of reasons, and runners and that community argue about this endlessly. There are papers in both sides, in both directions, I'm sure I'll hear about some of this in the comments. I'm not really going to take a stance on this as a consequence because the data are all over the place. However, I think there's a general logic that we can apply, and here I'm borrowing from some conversations and some information put out there by Dr. Andy Galpin, who I think is, of course, both an expert and thinks about these things in a really sound and flexible way, no pun intended. There are instances, for example, where an individual might want to do some static stretching to increase limb range of motion prior to doing weight training even if it's going to inhibit that person's ability to lift as much weight. Why would you want to do that? Well, for instance, if somebody has a tightness or a limitation in their neuromuscular connective tissue system someplace in their body and system that prevents them from using proper form, that they can overcome by doing some static stretching. Well, that would be a great idea as Dr. Galpin points out. Or for instance, if proper stability within the movement requires increasing limb range of motion in some way, well then compromising the use of greater loads could be greatly offset by doing some static stretching to improve, say, hamstring flexibility or another muscle group flexibility. So, we can't always think about just what's going to allow us or inhibit us from using the maximal amount of weight or from running as far as we want to run as fast as we want to run. There are instances where people are trying to overcome injuries where they're trying to come back from a repetitive surgery or something of that sort, coming back from a layoff where some additional static stretching prior to cardiovascular, or weight training, or skill training, or sport of some kind is going to be useful because it's going to put us in a position of greater safety and confidence and performance overall, even if it's adjusting down our speed or the total amount of loads that we use. So, it's you that needs to consider whether or not for you and within a given training session you want to do static training, I should say static stretching range of motion training prior to or after that training session. And similarly, there are a lot of data pointing to the fact that doing some dynamic or even ballistic stretching prior to skill training, or cardiovascular, or weight training can be beneficial in part to warm-up the relevant neural circuits, joints, and connective tissue, and muscles, and as well to perhaps improve range of motion or ability to perform those movements more accurately, with more stability, and therefore with more confidence. And while Dr. Andy Galpin would never name any protocol after himself, he's far too humble to do that, I've named a couple of protocols after him, particularly the Galpin equation for hydration, because he was willing to stick his neck out there and put down some specific numbers that people could follow in order to ensure proper hydration during training, you can look up the Galpin equation elsewhere. You can just Google it or look elsewhere and find it. And Dr. Galpin has also been very thoughtful and generous, and I think very accurate in offering a kind of a general organizational logic for how to think about the goals of a particular training session, and thereby to decide whether or not you're going to do ballistic, or static stretching, and so on and so forth. So, we can refer to this general approach as Galpinian.

01:45:41 Stretching, Relaxation, Inflammation & Disease

Galpinian, is that right? Galpin-ian logic, Galpinian logic. Thus far, we've been talking about stretching for sake of increasing limb flexibility and range of motion, but there are other reasons perhaps to embark on a stretching protocol that include both our ability to relax and access deep relaxation quickly, as well as even to reduce inflammation and perhaps even combat certain forms of cancer. And if that sounds really far-fetched, I want to emphasize that the study I'm about to share with you in a moment was actually carried out by one of the directors of a division of the National Institutes of Health. And this was the work of Helene Langevin, who's a medical doctor, has done really important work on the mechanisms underlying things like acupuncture and has approached all that from a very mechanistic viewpoint. Right, so not looking just at the effects of acupuncture, but really trying to understand what sorts of cytokines, inflammatory molecules, and pathways are activated? What sorts of neural mechanisms get engaged by things like acupuncture that impinges on the fascial tissues and so forth? And Dr. Langevin is currently Director of the National Institutes of Complementary Health and Medicine at the National Institutes of Health. So, this is a major division supported by tax dollars that support systematic mechanistic exploration of things like respiration, meditation, yoga, acupuncture. So, this is serious science applied to protocols and approaches that have been used for some period of time, but really aimed at trying to understand what would the best protocols be to evolve new protocols? So, there's a really interesting study done in animal models, but I think it's a powerful enough result that I think we all should pay attention to it. The title of this paper, and, again, the last author is Dr. Langevin herself, is Stretching Reduces Tumor Growth in a Mouse Breast Cancer Model. And yes, you can get mice to stretch, it turns out that if you gently lift up mice by their tail and they'll hold onto their cage, there's a way in which you can mechanically stretch them in a way that doesn't harm them. First, I should mention that Dr. Langevin and others have shown that just a brief whole body stretch of that sort induces an increase in activation of the parasympathetic arm of the autonomic nervous system, again, not arm, limb arm, but the aspect of the autonomic nervous system that creates a whole body, whole nervous system shift toward more relaxation. So, yes, indeed stretching induces relaxation at a systemic level, not just at a local level. And I think that's important, probably not surprising to those of you that use stretching regularly, but yes, it does indeed relax us. Yes, you can do this in mice and see that in mice as well. Here's what they did for this current study, or I should say this was a study published in 2018 in Scientific Reports. They write, "Recent studies have shown that gentle daily stretching for 10 minutes can reduce local connective tissue inflammation and fibrosis." Now, that's local tissue inflammation and fibrosis as well we now know as systemic inflammation and can induce relaxation systemically. In this case, they focused on mice, not humans. And mice were randomized to a stretch versus no stretch condition and were treated for 10 minutes once a day for four weeks. So, it's 10 minutes of this passive whole body stretching a day for four weeks. What's remarkable, I mean, just I have to say is just striking is that tumor volume in these mice, they were able to induce tumors in these mice and the tumor volume at the end point was 52% smaller in the stretch group compared to the no stretch group. This is a highly significant effect, and they point out in the absence of any other treatment. And they explored whether or not cytotoxic immune responses were activated and a number of other features. They weren't able to get too deeply into the underlying mechanisms, but this is pretty remarkable. Even three weeks into stretching protocol, this daily stretching protocol for these mice tumor volume was reduced, I mean, by it's almost halved, this is pretty incredible. So, they have these measures of tumor volume and the only difference in the way these animals were treated and handled was the introduction of this daily stretch. I find this result to be, of course, limited in to the extent that it's done in an animal model, not in humans, we have to point it out, but as they point out in their discussion, "Our results demonstrate a 52% reduction in mammary tumor growth over one month in mice undergoing stretching for 10 minutes a day without any other form of therapy." Do they think that stretching itself is changing the tumor size? No, in fact they raise the possibility that stretching because of its impact on the fascia might even create micro environments that are more permissive for tumor growth in certain instances, so they're careful to emphasize what I also believe to be the case, which is that it's unlikely that the stretching itself was directly acting to reduce tumor size, but rather that there's this possible link between inflammation and immune exhaustion mechanisms that if you can periodically relax a nervous system, here through stretching, that it can affect certain pathways related to the immune system that would allow the immune system to combat tumor growth to a significant degree. So, again, even though this is a study in mice, it argues that relaxation induced by stretching can have a powerful influence on mammary tumor growth. Again, a huge effect carried out by one of the premier labs and individuals who do this sort of work and think about this sort of thing. And, of course, I want to point out it wasn't just Dr. Langevin that did this study, there are a number of co-authors on the study we will provide a link to the co-authors,

01:51:37 Insula & Discomfort, Pain Tolerance & Yoga

excuse me, we will provide a link to the study so that you can peruse it in more detail if you like. Now, as a related and somewhat final point, I'd like to return to this idea and this place, this real estate within our brain that we call the insular cortex, the insula. As you recall, way back at the beginning of this episode, we were talking about the von Economo neurons, that Constantin von Economo the Austrian scientist discovered. And the fact that we are able to make and perform interpretations of our internal landscape pain, our dedication to a practice, for instance, whether or not we are in pain because it's a practice that we are doing intentionally and want to improve ourselves, or whether or not it's pain that's arriving through some externally imposed demands or situations. Well, the insula is handling all that. And fortunately, there's a wonderful paper that was published, it was a few years ago now in the journal Cerebral Cortex, which is a fine journal. This is the year 2014 entitled Insular Cortex Mediates Increased Pain Tolerance in Yoga Practitioners. I'll tell you why I like this study. I'm personally not a practitioner of yoga, I've taken a few yoga classes over the years, I've done some of the hot yoga classes. Those rooms can get really, really warm, I confess, and I've done the kind of standard yoga every now and again. It's not something that I've kept up regularly. This study explored the effects on brain structure volume in yoga practitioners. And for those of you out there that are aficionados in yoga, they pulled subjects from having backgrounds in the... Here, I'm probably going to mispronounce these different things, and forgive me, the Vinysasa yogas, the Ashtanga yogas, the Iyengar yogas, the Sivananda yogas. Okay, so some people were new to these practices, some were experienced. That the important take aways were that they took these yoga practitioners and they didn't explore their brain structure in the context of yoga itself, they looked at things like pain tolerance. So, they used thermal stimulation, basically they put people into conditions where they gave them very hot or very cold stimuli and compared those yoga practitioners of varying levels of yoga experience to those that had no experience with yoga, so-called controls. And they found some really interesting things, there are a lot of data in this paper, but here's something I'd like to highlight. The pain tolerance of yoga practitioners was double or more to that of non-yoga practitioners, even for those that weren't doing this so-called hot yoga. Right, they also found that pain tolerance was significantly greater, both for heat pain and for cold pain. They also found significant increases in insula, again, the insula, this brain region, gray matter volume. Typically, when we talk about gray matter, we're talking about the so-called cell bodies, the location in neurons where the genome is housed and where the kind of all the housekeeping stuff is there. And then white matter volume tends to be the axons, the wires because they're ensheathed with this stuff that appears white in MRIs, and indeed is white under the microscope, and indeed is white, it's actually lipid, which is myelin. So, increased gray matter volume of the insula is a significant finding because what it suggests is that people that are doing yoga have an increased volume of these areas of the brain that are associated with interoceptive awareness and for being able to make judgements about pain and why one is experiencing pain, not just to lean away from pain, but to utilize or leverage or even overcome pain. So, there are many studies of yoga and meditation out there, few that have as much mechanistic detail as this one. And in fact, there's a beautiful figure, Figure 3 in this paper that shows that the gray matter volume of this particular brain region scales in a almost linear way with the duration of yoga practice that somebody has been taking on in years. So, people that had, well, hey had a few subjects that have up to 15 or 16 years of yoga practice had much larger left insula gray matter volume, bigger brain areas associated with these abilities. And I find this interesting because there are a lot of activities out there that don't create these kind of changes in brain volume, especially within the insula. So, it appears that it's not just the performance of the yogic movements, but the overcoming or the kind of pushing into the end ranges of motion and to push through discomfort to some extent, of course, we want people doing that in a healthy, safe way, but that allows yoga practitioners to build up the structure and function of these brain areas that allow them to cope with pain better than other individuals, and to cope with other kinds of interoceptive challenges, if you will, not just pain but cold, not just pain but discomfort of being in a particular position to do that. And again, we wouldn't want people placing themselves into a compromised position literally that would harm them, especially given that earlier we heard that Microstretching of the kind of non-painful sort low-intensity sort is actually going to be more effective for increasing end range of motion. But this study really emphasizes the extent to which practitioners of yoga don't just learn movements, they learn how to control their nervous system in ways that really reshapes their relationship to pain, to flexibility, and to the kinds of things that the neuromuscular system was designed to do. And as a final point, there's a beautiful graph in this paper, beautiful I think because it explores some of the more subjective dimensions of yoga and insula function, which is a here I'll read it out in the nerdy form and then I'll explain what it means, "This is a frequency histogram of categories of mental strategies used by yogis versus controls during the cold pain tolerance task." What they're describing here and showing is quantitatively how people are conceptualizing cold pain in order to get through it. And the different categories are, for instance, distraction, right? Some people just choose to distract themselves from pain or to attempt to, other people will try to ignore it, it's a lot like distraction, but nonetheless, to engage in a negative emotion, sort of like, "[growls] like I'm going to dig, I'm going to be in resistance to this." Control subjects tended to use those approaches, whereas practitioners of yoga tended to use other sorts of subjective approaches like positive imagery to some extent, the ability to relax despite the extreme cold, the ability to quote-unquote accept like, "This is just happening," despite the extreme cold, to observe, to third person themselves. And the greatest effect, of course, was to breathe, to focus on their respiration as a way to deal with this challenge, this cold challenge. Now, all of that are subjective data, but I want to remind you that the practitioners of yoga are not just using entirely different mental strategies, but they are far more effective at dealing with pain, their pain tolerance is much higher as evidenced by the other data in the previous graphs in the paper. So, while this podcast episode is most certainly not about yoga per se, it's about flexibility and stretching, flexibility and stretching are elements within yogic practices. And, of course, yogic practices involve breathing and mental work, and a lot of other things balance, et cetera. It's a vast landscape as as many of you know. But I think that if ever there was a manuscript that pointed to the utility of something like yoga for sake of tapping into a particular set of brain circuits and mechanisms that could wick out into multiple dimensions of life, so day-to-day life, stress, challenges in dealing with all sorts of external stressors, career-related, family-related, relationally, et cetera, et cetera, excuse me, but as well for increasing range of motion for increasing flexibility. So, if ever there was a practice that one could embark on that would not only increase flexibility and limb range of motion, but would also allow one to cultivate some improved mental functioning as it relates to pain tolerance and other features of stress management that no doubt wick out into other areas of life, appears that yoga is a quite useful practice. And so, for those of you that are interested in increasing limb range of motion and you're already a practitioner of yoga, great. I can imagine that someday there'll be another study like this one and you'll be in that 10 or 15-16 year practitioner graph. You'll be that dot way out on the far end of the graph that shows that your insula is that much bigger than the rest of ours, and therefore your internal awareness, and pain thresholds, and stress management will be that much better,

02:00:36 Tools: Summary of Stretching Protocols but of course, yoga isn't the only way to increase limb range of motion and flexibility. Up until now, we've described a number of different ways to do that and we've arrived at some general themes and protocols. Again, those themes and protocols will be distilled into some specific and precise list in our Neural Network Newsletter, but we can revisit a couple of them now just in summary and synthesis. Static stretching appears to be at least among the more useful forms of stretching. So, low or zero momentum stretching typically at end range of motion. I love this concept of Microstretching, even though it's just a couple of studies that have addressed whether or not high-intensity or low-intensity static stretch holds are more beneficial. The idea and indeed the data that low-intensity, so 30-40% of what would one would consider painful appears to be more effective than 80% of that threshold. I find that incredibly interesting. And then, there's this idea of frequency, it really does appear that getting at least five minutes per week total of stretching for a given muscle group is important for creating meaningful, lasting changes in limb range of motion. And that is best achieved by five day a week, or six day a week, or even seven day a week protocols, but those can be very short protocols limited to, say, three sets of 30, maybe in 45 or 60 seconds of static hold. Although, 30 seconds seems to be a key threshold there that can get you maximum benefit. There is no need to do full 60-second holds unless you're doing fewer total sessions per week. And, of course, to always warm-up or to arrive at the stretching session warm. And then, of course, there are the other forms of stretching that we touched upon a bit, things like PNF. And we talked about why PNF works, things like the spindle and the Golgi tendon organ reflexes that are built into all of us that we arrive in this world with. And of course, the other forms of stretching that are known to be effective and important, such as dynamic and ballistic stretching. Again, stretching protocols that involve a lot of momentum in order to improve range of motion for performance of particular types of work that one is about to embark on. Typically, that would be physical work, but a whole interesting and unexplored landscape is the extent to which changing limb range of motion and different types of body movement

02:03:00 Zero-Cost Support, YouTube Feedback, Spotify & Apple Reviews, Sponsors, Momentous Supplements, Instagram, Twitter, Neural Network Newsletter

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