

Dr. Craig Heller: Using Temperature for Performance, Brain & Body Health | Huberman Lab Podcast #40

This episode I am joined by Dr. Craig Heller, Professor of Biology at Stanford University and world expert on the science of temperature regulation. We discuss how the body and brain maintain temperature under different conditions and how most everyone uses the wrong approach to cool off or heat up. Dr. Heller teaches us the best ways and in doing so, explains how to offset hyperthermia and hypothermia. He also explains how we can use the precise timing and location of cooling on our body to greatly enhance endurance and weight training performance. He describes how cooling technology discovered and engineered in his laboratory has led to a tripling of anaerobic (weight training) performance and allowed endurance athletes to run further and faster, as well as to eliminate delayed onset muscle soreness. Dr. Heller explains how heat impairs muscular and mental performance, and how to cool the brain to reduce inflammation and to enhance sleep and cognition. We discuss how anyone can apply these principles for themselves, even their dogs! Our conversation includes both many practical tools and mechanistic science.

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Timestamps:

00:00:00 Introducing Dr. Craig Heller, Physiology & Performance

00:02:00 Sponsors: Roka, Inside Tracker, Athletic Greens

00:06:45 Cold Showers, Ice Baths, Cryotherapy

00:10:45 Boundary Layers

00:11:55 Cooling Before Aerobic Activity to Enhance Performance

00:14:45 Anaerobic Activity Locally Increases Muscle Heat

00:16:45 Temperature Gates Our Energy Use

00:19:00 Local Versus Systemic Fatigue: Heat Is Why We Fail

00:22:10 Cooling Off: Most Methods are Counterproductive

00:26:43 Exercise-Induced Brain Fog

00:27:45 Hyperthermia

00:31:50 Best Body Sites for Cooling: Palms, Foot Pads, Upper Face

00:38:00 Cooling Your Brain via The Upper Face; Concussion

00:41:25 Extraordinary (Tripling!) Performance by Cooling the Palms

00:45:35 Enhancing Recovery, Eliminating Soreness w/Intra-workout Cooling

00:50:00 Multiple Sclerosis: Heat Sensitivity & Amelioration with Cooling

00:51:00 Enhancing Endurance with Proper Cooling

00:53:00 Cool Mitt, Ice-Cold Is Too Cold, 3 Minutes Cooling

00:58:20 How You Can Use Palmer Cooling to Enhance Performance

01:01:15 Radiation, Convection, Heat-Transfer, Role of Surface Area

01:04:40 Hypothermia Story, Ideal Re-Heating Strategy

01:11:40 Paw-Imer Cooling for Dog Health & Performance

01:12:45 Warming Up, & Varying Temperature Around the Body

01:17:35 Cooling-Enhanced Performance Is Permanent

01:19:55 Anabolic Steroids versus Palmer Cooling

01:24:00 Female Athletic Performance

01:25:18 Shivering & Cold, Metabolism

01:26:55 Studies of Bears & Hibernation, Brown Fat

01:31:10 Brown Fat Distribution & Activation In Humans

01:34:18 Brain Freeze, Ice Headache: Blood Pressure, Headache

01:37:50 Fidgeters, Non-Exercise Induced Thermogenesis

01:39:44 How Pre-Workout Drinks, & Caffeine May Inhibit Performance

01:43:42 Sleep, Cold, Warm Baths, Screens, & Socks

01:48:44 Synthesis

01:49:30 Supporting the Podcast & Scientific Research

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- Welcome to The Huberman Lab Podcast, where we discuss science and science-based tools for everyday life. [energetic rock music] I'm Andrew Huberman, and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today I have the pleasure of introducing Dr. Craig Heller as my guest on The Huberman Lab Podcast. Dr. Heller is a professor of biology and neurosciences at Stanford. His laboratory works on a range of topics, including thermoregulation, down syndrome, and circadian rhythms. Today we talk about thermoregulation, how the body heats and cools itself, and maintains what we call homeostasis, which is an equilibrium of processes that keeps our neurons healthy, our organs functioning well. And as Dr. Heller teaches us, thermoregulation could be leveraged in order to greatly increase our performance in athletics and mental performance as well. Learning to control your core body temperature is one of the most, if not the most powerful thing that you can do to optimize mental and physical performance, regardless of the environment that you're in. He also dispels many common myths about heating and cooling the body, including the idea that

putting a cold pack on your head or neck is the optimal way to cool down quickly. And in fact, as Dr Heller tells us, it actually can be counterproductive, and lead to hyperthermia. It's a fascinating conversation from which I learned a tremendous amount of new information, and we didn't even get into the other incredibly interesting work that Dr. Heller does on down syndrome and circadian rhythms and sleep. So we hope to have him back in the future to discuss those topics. As you'll soon see, Dr. Heller is a wealth of knowledge on all things human physiology, biology, and human performance. It's no surprise then that he's been chair of the biology department at Stanford for many years, as well as director of the human biology program.

00:02:00 Sponsors: Roka, Inside Tracker, Athletic Greens

So if you're interested in human biology and how to improve your performance in any context or setting, athletic or otherwise, I think you'll very much enjoy today's conversation. 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 ROKA. ROKA makes sunglasses and eyeglasses that are of the absolute highest quality. I've spent a lifetime working on the visual system and I can tell you that the visual system has to go through a lot of work in order to maintain clarity of what you see when there are shadows, when you go into different types of indoor lighting, and so on, and a lot of glasses don't work well because you put them on and then you're in bright light and you can see fine, but then you move into a shadow and then you have to take them off and they don't adjust, or they don't adjust quickly enough. With ROKA, their eyeglasses and sunglasses are designed with the visual system biology in mind. So you always see things with perfect clarity. The glasses are also terrific, because they're very lightweight and they won't slip off your face if you're exercising, if you're running or biking. In fact, they were designed for the purpose of being able to be worn while you're engaging in those sorts of activities, or simply working at your desk. I happen to wear readers at night when I drive or when I work and I love their sunglasses, 'cause I can wear them anywhere. And also the aesthetics of their sunglasses and eyeglasses are terrific. Unlike a lot of other performance glasses that frankly make people look like cyborgs, the aesthetics on ROKAs are really terrific. You

could wear them anywhere you'd like to go. If you'd like to try RAOKA glasses, you can go to ROKA.com. That's R-O-K-A.com, and enter the code HUBERMAN to save 20% off your first order. That's ROKA, R-O-K-A.com. Enter the code HUBERMAN at checkout. Today's podcast 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'm a big believer in getting regular blood work done. And now with the advent of modern DNA tests, you can also analyze your DNA to see what you ought to be doing for your immediate and longterm health. We hear a lot these days about optimization, optimizing hormones, optimizing your metabolism, optimizing this, optimizing that, but unless you know the measurements of metabolic factors, hormones, and other things that are in your blood and DNA, you don't know what to optimize. With InsideTracker, it makes all of that very easy. They can come to your house to take the blood and DNA test, or you can go to a nearby clinic. They send you the information and you take those results. And unlike a lot of laboratories doing blood work out there and DNA tests, they have a simple platform, a dashboard that walks you through your results and helps you identify what sorts of nutritional or behavioral or other types of practices you might want to incorporate into your life in order to positively impact your immediate and longterm health. It's a very easy system to use, and you will gain a ton of information simply by doing that test, whether or not you end up making changes to what you're doing or not. If you'd like to try InsideTracker, you can go to insidetracker.com/huberman to get 25% off any of InsideTracker's plans. Just use the code Huberman at checkout. Today's episode is also brought to us by Athletic Greens. Athletic Greens is an all-in-one vitamin, mineral, probiotic drink. I've been using Athletic Greens since 2012. So I'm delighted that they're sponsoring the podcast. The reason I started using Athletic Greens and the reason I still take Athletic Greens once or twice a day is because it covers all of my nutritional bases. In fact, if people asked me, and I often am asked, what supplements should I take? I always recommend Athletic Greens. And in fact, if you were to take just one supplement, I recommend Athletic Greens for the simple reason that the vitamins, minerals, and probiotics, and adaptogens cover all your nutritional bases. And the probiotics optimize gut-brain health, which we now know is essential for mood, for immune system function, for metabolic function. It's just got so many great things in there. I really do feel better when I'm drinking my Athletic Greens. I mix mine up with some water, a little bit of lemon juice. And as I mentioned before, I'll drink it once or twice a day. If I travel, I might even

drink it a third time, just because of the additional stress on my mind and body. If you'd like to try Athletic Greens, you can go to athleticgreens.com/huberman to claim a special offer. They'll give you five free travel packs. So these little travel packs that make it really easy to mix up athletic greens if you're on the plane or in the car. And they'll give you a year's supply of vitamin D3K2. There is now ample evidence that vitamin D3K2 is supportive of the immune system and a bunch of other biological functions and K2 has been shown to be important for cardiovascular health. So again, if you go to athleticgreens.com/huberman, you'll get the Athletic Greens,

00:06:45 Cold Showers, Ice Baths, Cryotherapy

the five free travel packs and the year's supply of vitamin D3K2. And now for my discussion with Dr. Craig Heller. Great to have you here. - It's good to be here. - Yeah. It's been a long time coming. I know that I and many people have a lot of questions about the use of cold. So one of the things that's happened in recent years is that for many reasons, people have become interested in things like taking cold showers and taking ice baths for many different purposes. Sometimes this is introduced as just a general health tonic, but other times people get specific about how it can improve resilience or it can improve one's metabolism. Could you just tell me a little bit about what happens when I get into a cold shower or an ice bath? What are some of the basic responses at the level of metabolism? Obviously psychologically, we don't know exactly. It'll vary from person to person, but what happens when I submerge myself into an ice bath if I've never done it before? - Well, first of all, you get a tremendous shock. And what that's going to translate into is a bit of a shot of adrenaline. And I think this is really the so-called benefit, but I wouldn't call it a benefit, of the cryo chambers. You go into a cryo chamber and it's a shock. So you get a shot of adrenaline. So, sure. You're going to feel different when you come out. You've had a shot of adrenaline. But it doesn't necessarily translate into any benefit in terms of your physiology or performance, and so forth. Now if you take a cold bath or a cold shower, a couple of things are happening. One is you're going to stimulate vasoconstriction. So if anything, it's going to make it a little bit more difficult for your body to get rid of heat, because you're shutting off your avenues of heat loss. If you're in a true cold bath, the overall surface area of your body is so great that it doesn't matter if you're vasoconstricted, you're still going to lose heat. - Okay, so vasoconstriction, the constriction of, is it capillaries, vessels and arteries all

constrict or just one or two? - Well, this is an area of controversy. In general, when people talk of vasoconstriction, they talk of the overall skin surface, and that is not true. The primary sites of heat loss, which we're going to get into, are the palms of your hands, the soles of your feet, and the upper part of your face. And the reason these are avenues for heat loss is they're underlain by special blood vessels. And these blood vessels are able to shunt the blood from the arteries, which are coming from the heart, directly to the veins, which are returning to the heart, and bypassing the capillaries, which are the nutritive vessels, but high resistance. So you can tell when you shake someone's hand what his or her thermal status is. The hand's hot or it's cold. - Do you think that's part of the reason why humans evolved this practice of shaking hands? [Craig chuckles] Assessing each other's level of anxiety? We all know that a limp shake is pretty indicative of something and a firm handshake is indicative of something, as is the crushing handshake for that matter, right? - Yeah, I really don't know what the evolutionary origin of handshaking is, other than to get your hand away from your weapon, [chuckles] perhaps. - Right, a couple of questions before we get into these specialized vascular compartments on the soles, the palms and the upper face. You mentioned whole body immersion, like into an ice bath or very cold water up to the neck versus a cold shower. Is there something fundamentally different about those two, besides the fact that they both provide their release of adrenaline? Is there anything that's really important

00:10:45 Boundary Layers

to understand about the difference in the physiological response evoked by cold shower versus immersion in cold? - Well, there are differences that are more physical than anything else. So if you are in a cold bath and you're still, you develop a boundary layer. If you're in a shower, you can't develop a boundary layer. - Could you explain what a boundary layer is? - Yes, it's best to explain it in terms of a hot bath, 'cause everybody's experienced that. You get into a hot bath and, oh my God, it's really hot, almost painful. And then you sit down and eventually it doesn't feel so hot anymore, because the still water, which is close to your skin, is coming into equilibrium with your skin. So it's like having a blanket on you or an insulator on you. And then if you move around, you disturb that still water layer. You feel the hot temperature again. - I see, so if I were to get into a cold ice bath or very cold body of water of some kind and stay still, I'd likely feel warmer

at least until I - You're not going to be losing as much heat. - I see. - Right. - And then when I move in - If you flail around, if you flail around, then you're going to lose more heat.

00:11:55 Cooling Before Aerobic Activity to Enhance Performance

- Got it. - Yeah. But I think getting back to your original question about benefits, you have to keep in mind whether you're talking about aerobic activity or anaerobic activity, if you're referring to performance and exercise, and so forth. So if you're doing aerobic activity that you can sustain for a long time, your production of heat is rising gradually and is being distributed throughout your body. So eventually your body temperature is going to come up to a level that's going to impair your performance. So the benefit of a cold bath or a cold shower before aerobic activity is that you increase the capacity of your body mass to absorb that excess heat. - I see, so could you say that, in a rough sense, that a protocol that one might use if they're going to head out for a long run? - Yep. - Even on a reasonably warm day, not super hot, or maybe it is super hot, would be to take a cool shower before they go run. Would that be beneficial? - Sure, it'll take them longer to get to the sweat point and to heat up. - And what will that translate to in terms of a performance benefit? - Well, could increase your speed, or it depends on how you use that benefit. Some people are pacers. They will go at the same pace and then they will go farther. Or some people are, I'm going to say pacers and regulators and, no, no. Pacers or forcers. They will take that advantage and use it up as fast as they can. So they will go faster, but not necessarily farther. - I see, as far as I know, not many athletes, at least not the ones that I know, are getting into cool bodies of water, taking cold showers before they head out to train. But it sounds like there could be a real performance benefit there. - It could be a benefit. I know we're going to talk about our technology for cooling, but at one point our, I don't know if they're using it now, but our cross-country team, when they would go to compete in a very hot place, they would do their warm-up exercises, their stretching. Then they would extract heat before the beginning of the race. So I like to think of it as you have greater scope for heat absorption. - Interesting, about how long would one need to take one of these showers or cold immersions before heading out for a run? Roughly speaking, we don't have to get into details, because everyone's performance level and regimen is going to be different, where they live is going to be different, et cetera. - It's not as long as you think. It's

minutes. - Couple minutes? - Yeah. Because what's going to happen is as your core temperature goes down, you will eventually shut off your heat loss. And that keeps it from going below normal. So if you've warmed up and your temperature

00:14:45 Anaerobic Activity Locally Increases Muscle Heat

has risen by half a degree, let's say, it doesn't take more than a few minutes to extract that heat if you're vasodilated. - Interesting, and what about for the anaerobic athlete? The strength athlete. - Right. For the anaerobic athlete, and let's say they're doing several sets and how many reps, whatever they're doing, their core temperature's not going to rise that fast, because it's only certain muscles which are being used, but the temperature of those muscles will go up. - So it's a local effect. - It's a local effect, right. - Okay. So let's say, for sake of today, maybe for this discussion, if we assume that the basic workout, even though people do variation on this is 5 sets of 5 or 10 sets of 10. So for those listening, it would be 5 sets of 10 of 5 rep repetitions, or 10 sets of 10 repetitions, 10 by 10, 5 by 5. Yeah, so if somebody, let's say, is doing a large body compound movement, like barbell squats where there are a lot of large body movements, hip hinging, et cetera. But for instance, the biceps are not, they're involved, but more or less indirectly. - Right. - So the effect is going to be to heat up the quadriceps, heat up the hamstrings, heat up the glutes, this kind of thing. - Right. - I see. - And then during rest, that heat will leave the muscle, but it's not fast. And certainly the heat can't leave the muscle very fast while you're working out, because when the muscle contracts, it squeezes the blood vessels. And the only way heat gets out of a muscle is in the blood. And your muscle metabolism can go up 50 or 60-fold during anaerobic activity. That means the heat production in the muscle goes up 50 or 60-fold. The blood flow to that muscle cannot go up 50 or 60-fold. So you literally have the capacity to cook your muscles. [Craig chuckles]

00:16:45 Temperature Gates Our Energy Use

- So this is probably an appropriate time to just mention briefly what the underlying mechanism of this is. We will return to the specifics of what one can do to mitigate this heating up, but could you just explain the relationship between energy production ATP and pyruvate kinase and the role of heat there? - Sure. We don't get something for

nothing. So like a steam engine, most of the energy in our food is lost as heat. So we are roughly about 20% efficient. So of the energy that we take in in our food, about 20% of that can go into doing work, and the rest of it is lost as heat. Now we're mammals. We use that heat to keep our body temperature considerably above the environment. But if you raise body temperature a few degrees higher, you're in trouble, that's hyperthermia. So individual muscles can reach hyperthermic limits before you might experience it in the whole body. So to keep you from damaging your muscle by hyperthermia, we have fail-safe mechanisms. And one of those fail-safe mechanisms is an enzyme which is critical for getting fuel. In other words, the results of metabolism of glucose, getting that fuel into the mitochondria, which is making our major coinage of energy exchange, ATP, okay? So that particular enzyme is temperature-sensitive. So when the muscle temperature gets above 39 or 39.5, it shuts off. And that essentially shuts off the fuel supply to the mitochondria. That's when you cannot do one more rep. - So failure, could we say that- - Muscle failure. - One component of muscular failure is overheating of the muscle locally? - Right. - There're probably other things too. - Well, if you, yeah, if you lack oxygen, but our oxygen delivery is pretty good to the muscle. If you run out of glucose, yeah. That's going to impair you. But the most immediate, the most immediate impairment of muscle activity, muscle fatigue, in other words,

00:19:00 Local Versus Systemic Fatigue: Heat Is Why We Fail

is the rise in temperature of the muscle. - Interesting, I want to talk about how that muscle fails locally, but I have this burning question in my mind that I cannot seem to answer for myself. I'm hoping you can answer it for me. So let's say I'm doing five sets of five with squats. I hit fit muscular failure at a given weight. And according to what I now know, it's my quadriceps and the muscles associated, I mean, with the squat that have failed because of this heat triggering, this mechanism triggered by heat that shuts off the muscle. But my biceps are nice and cool, you're telling me. They're not doing too much work. It's only indirect work. So why is it that I can't set the bar down in the squat rack, walk over and do barbell curls with the same intensity that I could if I were to do those barbell curls fresh, not having done anything prior? - Well, you will still have a fatigue curve with your upper body, okay? And that will be influenced by any rise in temperature that has been generated by your lower body exercise. - So temperature in both cases is the limiting factor? - It's one limiting factor. It's one limiting factor. - I find that amazing. I

find that amazing because I always thought naively that the reason muscles fail is because, quote, don't have the strength to do another repetition. That you lack glycogen or some ability to access that glycogen. But of course, we still have glycogen. It's naive for me to think that, because if I wait three minutes and go back, I can do those repetitions again. So the glycogen wasn't restored in that three minutes, obviously it was there. - Right. - So I realized there might be other mechanisms involved. Sounds like heat is, if not the dominant mechanism that prevents more work. It's one of them. - It's one of them. And it's a quick one. It's a fast one. So it can happen with, let's say you are a really experienced weightlifter, okay? You may be doing very, very high weights with sets of five or six. - Yeah, to be clear for the audience, I'm not doing very high weights for sets of five. [chuckles] [Craig laughs] I'm not particularly strong. I'm not super weak, but I'm not particularly strong, but Craig's referring, in the general sense, to you. So why is it that if I finish a set of squats, I can't simply cool off my quadriceps by throwing a nice cool towel on my quadriceps. Why is that not the best way to go about it? - Because your body surface is a very good insulator. Okay, we think we don't have fur, and therefore we're not insulated, but the skin, the fascia, the muscles underneath, they're all very good insulators. And that's why I said earlier that the way the heat gets out of the muscle is in the blood. - So I want to step through a couple other portals by which one might think that heating and cooling would be ideal. And then get back to these. - Sure.

00:22:10 Cooling Off: Most Methods are Counterproductive

- Specialized surfaces on the hands, the feet and the face. - [Craig] Yeah. - So if throwing a cold towel or even ice cold towel on my quadriceps isn't going to work or standing in front of the fan, because I'm insulated from that cool, I can't cool off my blood fast enough. What about drinking 16 ounces of ice water? - Sure. You can do that. But you can calculate how much heat that can absorb, okay? And you can't continue drinking liters of ice water. You're going to dilute your blood and have other problems. But yes, it'll help. Sure, it will help. But it doesn't have the full capacity you will need. - What about an ice pack to the back of my neck or to my head or squeezing the cold sponge over the head? I'm deliberately moving through these options, because these are the ones that we see most often. We were actually just watching the Olympic track and field trials last night up in Oregon. I'm a huge track and field fan. And there were a lot of sponges on the backs of necks before, in between, and after events. And how

good is that or how poor is that as a strategy? Since now we know that being overheated locally and systemically throughout the body is a serious limiting factor on performance. - Well, you have to understand something about our thermoregulatory system. We have a thermostat just like you have a thermostat in your house. And that thermostat is in the brain, okay? - Do we know the specific site? - Yes. - Yes. - It's called the preoptic anterior hypothalamus. It does many things in terms of physiological regulation, but it serves as a thermostat. Now that thermostat has to have information. It has to have input. Where does that input come from? It comes from our overall body surface where we sense temperature, okay? So one of the things that can happen when you're overheated is that you can send in a cold stimulus to your thermostat and that sort of like wanting to cool your house by putting a wet washcloth over your thermostat, it's doing the wrong thing. So we've actually had experiences where we've had people exercising, getting overheated, and then cooling the body surface, and they say it feels great. This is fantastic. And their core temperature is going up. - Well, I think this is such an important point. First of all, I was weaned in a laboratory where there were always battles over the temperature in the lab. So people were always putting ice packs on thermostats or putting fans towards thermostats and trying to play this game. Good to know we were all being foolish, even though we were neurobiologists. Putting a cold towel over my torso or putting ice on the back of my upper back, you're saying could actually heat up my core? - It'll at least decrease your heat loss, your rate of heat loss as you're going to raise the issue a little later, I know, and that is our natural portals for heat loss. So you can think of the natural portals for heat loss as our air conditioners, okay? The thermostats in the brain and the information to the thermostat is coming from the overall body surface. So what can happen if you, let's say, cool the torso with an ice vest, you can actually cause vasoconstriction of your portals, your heat loss portals. So that's what impairs the rate at which you're losing heat. It feels good. Now back to the head, that's really interesting. The major blood flow to the brain comes up four arteries through the neck. There's the carotid arteries and there's the vertebral arteries. So when you put a cold towel around the neck, you're going to be putting a cold stimulus into the brain. And that's great for protecting the brain. You want to protect the brain, but it's also going to make you feel cooler than you are. So you will think you're ready to go again quickly when you've just essentially cooled the thermostat. - This is an important point. And there's a lot of interest nowadays, and people doing marathons, and even some people do these ultras, ultra running, which I guess is everything longer than a marathon. And

last man standing, last man, last woman standing kind of things. So you're saying that if somebody's hyperthermic, they could trick themselves into subjectively thinking that they are cooling off by putting a towel and that they can go further, but their brain could cook?

- Well, if they stop the cooling,

00:26:43 Exercise-Induced Brain Fog

then that hot blood from the body core is going to go to the brain. - Interesting, well, it's a bit of a tangent, but many people report after long bouts of exercise, or even just very intense bouts of exercise, feeling a kind of brain fog or mental fatigue. I assumed that that was due to lowered brain oxygenation post-exercise, but is it possible that there is some post-exercise effects on heating and cooling of the brain that might impact cognition, or I should say negatively impact cognition? - It's certainly possible because we know that rise in temperature decreases cognitive capacity. I mean, you can experience that yourself. You can get on a treadmill, and follow your temperature, and then just do a simple activity like adding and subtracting. You get to about 39 degrees, you can't do that anymore. You can't just calculate how long you've been on the treadmill. - So the phrase cool, calm and collected is- - Cool, calm and collected. - That's the goal

00:27:45 Hyperthermia

in all pursuits. - That's right. - So I want to talk about these portals, because you've mentioned them a few times. Before I ask about what the portals are exactly and how they work and how they can be leveraged for performance, there's a question that my neurobiologist self can't resist, but ask. We have this thermostat in the preoptic area of the hypothalamus, which is interesting to me, the medial preoptic area is also one that's known to be sexually dimorphic, depending on testosterone exposure early in life, or et cetera. Although people should just note that it's not actually testosterone that creates these sexual dimorphism, these differences. Actually testosterone converted into estrogen. It's actually estrogen is the effector, which is fascinating. Nonetheless, we've got this area that acts as a thermostat. And you said it's collecting information from the whole body. Does that mean that there are pathways, as the neuroscientists like you and I refer to them, as these afferent or input pathways from the body to the preoptic area, is

there a map of our body in the preoptic area? 'Cause I have to imagine that you can't have the information just coming from the left shoulder, just from the right toe. It sounds like you need a pretty, probably a pretty crude map, but that you need a complete map of the body surface there. - Well, you don't need a complete map in the hypothalamus. I mean, that thermal afferent information that you've mentioned, it also goes to the somatosensory cortex. So you know if an ice cube has touched you on the back, but that doesn't necessarily translate into a change in, let's say you're shivering or sweating. So the information that's going to the hypothalamus is more integrated representation of body temperature. - So it's sort of an average of what's happening- - It's an average. - Across the body. So if I were to, let's say I get hot on a hot day and Popsicles, when we were in summer camp, I went to a sports camp near here actually, and we'd run around like crazy. And then we'd get into the shade if we could, but we were, Popsicles. It was all about Popsicles. - Brain freeze. - Or the kids were putting ice cubes down each other's shirts or something. But that's an average, because other parts of the body aren't exposed, the mouth is exposed to the ice in the Popsicle case or the cold cubes are in the hands. As you said, it feels really good. - It feels good. Yeah. - But it sounds like it feels deceptively good, because in reality could still be quite warm internally. - Absolutely. Yeah. - Interesting. - Yeah. You can feel great and have a dangerously hyperthermic temperature, but I should say that when you get into the danger zone, things get bad fast. - What are some of the symptoms that people could be on the lookout for for hyperthermia? - Essentially, it's almost ironic that if individuals are transitioning into heat stroke, they actually vasoconstrict and they stop sweating. And that's a pathological situation. I couldn't begin to explain it. But essentially you are just feeling exhausted. You're feeling miserable. The heart rate is very high. Your heart rate goes up as your core temperature goes up, called cardiac drift. So you just feel rotten. But that's why since it's not a danger signal that you can translate immediately into, oop, I'm going into heat stroke, that's why people can overcome their bad feeling with motivation to continue going, to work harder. So there've been a number of high profile athletic deaths due to heat stroke that were during practice. Not in competition when people are really trying to do it,

00:31:50 Best Body Sites for Cooling: Palms, Foot Pads, Upper Face

but in practice, which shows they were just motivated to push. - So let's talk about these

magnificent portals that not just humans, but other animals, mammals are equipped with. So if putting cold on the neck or on the head or on the torso is not optimal, what is optimal? And maybe walk us through a theory as to why we would have these portals located where they are. And then we can talk about how one might leverage them for performance. - Okay, where the portals are, are in the glabrous skin, big word, okay? Glabrous just means no hair. So it's the hairless skin. You say, well, most of my body is without hair. No, most of your body has hair follicles. We are mammals, mammals have fur. We've lost the fur, but we still have that hairy skin phenotype all over our body, except, except for those skin surfaces where our mammal relatives didn't have fur. So the pads of the feet. And for the primates, upper part of the face. For rabbits, no portions of the ears, the inner surfaces of the ears- - Ah, never thought about that. For bears, the tongue. Bears have big tongues, huge tongues. [chuckles] - I didn't know that either. I haven't been that close to a bear yet. - Haven't had a leaking match with a bear. - Not yet. No. - So anyway, our mammalian relatives can't lose heat over their overall body surface. So probably very early on in mammalian evolution, they evolved these special blood vessels in the limited surface areas that don't have fur. And as I said, what these blood vessels are are shunts between the arteries and the veins. Arteries and veins are both low resistance vessels. So you can have high flow rate. Capillaries, which normally are between arteries and veins are high resistance because they're very tiny, okay? - Is it fair to say that what I was taught is that blood flows from arteries, then to capillaries, and then to veins, and then back to the heart. So it's sort of like from the heart through arteries, then through these little capillaries, which are like little estuaries and streams and then to the veins, back to the heart. Is that generally true? - Yeah, absolutely. - Okay, so what I learned in basic physiology is still? - Is still- - I wouldn't get an F in your class? - No. - Maybe a D or C, but not F. - So that's excellent. - Okay. And so you're saying that in this glabrous or beneath the glabrous skin. - There are these shunts. - And those go directly from arteries to veins? So you skip the capillaries- - Capillaries, yep. - And is it actually, as long as I'm, say that in the skin, when I feel the pads of my hands, how deep to the surface do these vessels reside? - They're below the, obviously the epidermis. So if you are warm and you look at the palms of your hands, they are fairly red and the backs of your hands aren't. You don't have these vessels in the backs of your hands. Now if you take a glass, like a water tumbler, right? And you grab it, you can see if you squeeze a little bit, the hand goes white. That's because you've shut off that blood flow. - Oh, interesting. I'm going to do that little home experiment. - So if you're

bicycling on a hot day, you don't want to be grabbing your handlebars all the time. You want to periodically. [chuckles] - Well, this is important. I know you're privy to some really amazing results that we're going to talk about, but I actually heard you say this during this lecture recently that Stanford held about human performance that we were both part of. And you mentioned this, that if you're cycling and you're working hard and you want to be able to do more work, we now know why you want to remain cool in order to continue to do work, and if you get too warm, that's bad, that gripping the handlebars too tightly will actually limit your performance. - Right. - And that's probably also true on the Peloton or any other kind of device or the skier or anything like that. - Right. - So loosen the grip, or if you safely can, you want to actually expose your hands to the world? Now what about for people wearing gloves? What about the, to me that just seems crazy based on everything you're telling me. - Well, gloves definitely impede heat loss from the hands, just as socks impede heat loss from the feet, okay? So if you want to maximize your heat loss, you want to have as thinner protectors as possible on your hands. And of course the feet are more problematical, because you have to be using them in certain ways. - Some people run barefoot. - Yeah. Well, yeah. - Yeah. That's become somewhat popular. It seems like it kind of came and went. They had those toe shoes things, but they looked so ridiculous that I think most people just were willing to take the performance hindrance of regular shoes. - Actually we had a track coach here at Stanford who for a while was famous for introducing training without shoes, running. - Interesting. - And he thought it was because it changed the posture of the runner. And I think it was just due to the fact that he was increasing the capacity of his runners to lose heat. - Interesting, yeah, so heating up at the level of the hands obviously is going to hinder performance. So how about with running? I noticed, I ran cross country briefly in high school, and not particularly well at that, but that we were told to run as if we were holding crackers in our fingers or something like very lightly, and to keep hands kind of loose. So running like this would actually be more beneficial performance than, or gripping a phone, which is probably what most people are doing nowadays, right? - Right. - Interesting and- - Once, I'll tell you a experience I had once. I was in Alaska in the winter and I went out running and I absentmindedly forgot gloves.

00:38:00 Cooling Your Brain via The Upper Face; Concussion

And I realized this after a short period running, because the backs of my hands were

aching from the cold, the palms of my hands were sweating and were hot. - Oh, amazing. Amazing. So these compartments are a real thing. And you mentioned the upper half of the face- - The upper part, that's where our primate ancestors don't have fur. - And the bottoms of our feet. So let's just take a moment and talk about some of the more amazing results that have been associated with proper cooling of these glabrous skin surfaces. - Let me introduce one more thing. - Sure. - Because you asked earlier about the pouring of water on the head, okay? One of the things which is not appreciated fully is that the blood which is perfusing these special blood vessels in the face above the beard line, that's the non-hairy skin, that blood then returns in the venous supply to the heart, but it actually does it in a very strange way. It actually goes through what are called, I'm blocking on the name now. - Take your time. - These are blood vessels that go through the skull, okay? And that's why the scalp bleeds a lot if you cut the scalp. And these blood vessels which are called, I want to say emergent, but it's not emergent. It's a word that means leaving. These blood vessels were primarily thought to be ways that blood is leaving the brain. But when you're overheated, the direction of flow in those blood vessels reverses. So the cool blood that's coming from your facial region goes into that circulation and actually is a cooling source for the brain. So you can cool the brain. You can have a cooling effect on the brain by pouring water on your head. - Interesting, so that practice, which we, at least for me, I most commonly associate with combat sports, where the fighter goes to their corner. They usually sit down on a stool, unless they're trying to do some mental warfare from the corner, in which case, they don't even take a seat. And their corner crew will squeeze a glove, excuse me, a sponge full of cold water over them, that you're saying is somewhat effective in cooling the brain? - Yeah, it's one of the natural mechanisms for cooling the brain. - I want to return to this at some point as well, but is there any known benefit to cooling the brain in terms of offsetting physical damage, offsetting the negative effects of concussion. Because one of the reasons why fighters will often get, on the back, a cold item on the back of the neck or on the head is not just to cool them down, but the theory is that it might offset some of the damage of neurons. - I just can't comment on that. I'm aware of those ideas, but they're controversial. One of the things that you want to do for injury to the brain is to decrease swelling. And one of the ways that you decrease swelling in many parts of the body is to cool. It decreases inflammation. It decreases the blood flow. So I think it's a really interesting topic

00:41:25 Extraordinary (Tripling!) Performance by Cooling the Palms

and it's something that should be investigated. It's kind of hard to investigate. - Yeah, interesting. Okay. So I hear these stories. And I've seen the data. So I believe the stories. Maybe tell us a story about an observation that your group has made with respect to anaerobic exercise and proper cooling of these glabrous surfaces. And we can talk about the technology. Maybe give us the dips example first. - Okay. - So of course, I think most people are familiar with dips. You're supposed to, I guess- - Raise and lower your body. - Yeah, raise and lower your body, raise and lower your body mass usually with your legs dangling down. Sometimes people strong enough to attach a weight there and they'll do, it's essentially a compound upper body exercise. - Right. - One dip would not be particularly impressive for most people. 100 would be very impressive. 20 would be impressive for some, et cetera. What happens when a skilled athlete comes in and does dips for multiple sets. And then what happens when they cool properly using the glabrous skin surface? - This was a story that occurred early on in our investigations when we first made the discoveries that cooling has a benefit to increase your work volume, your capacity to do more reps, okay? So the word got over, I think, to the 49ers camp. And one of their players, Greg Clark, who was a tight end at the time. He had been tight end at Stanford. He decided, or I don't know if he was asked, or what, to come over and check it out. So Greg came over and we said, "Greg, what are you good at? What activity do you like to do?" He said, "Dips. I can do a lot of dips. I can do 40 dips in a first set. And I can probably do five sets. That's a usual workout for me." And we said okay. So he came over to the gym one day and that's exactly what he did. He did 40 dips the first set, and then maybe 25 and 15 and down, down- - Do you recall roughly what kind of rest periods he was taking between sets? - Yeah, we standardized the rest period to three minutes, because that's what we had set on for cooling as the injure- - That's a good long rest period. - Yeah. It is. - It's still a lot dips. - Yeah, it's actually a longer rest period than many people would prefer during workouts. They want to make the most of the time- - Not me. I prefer to take as much rest as I possibly can, yeah. - So several days later he came back and his first set, he did, I think, maybe 42, a little bit better, but now people were standing around and watching. So there was a little impetus there to show off. So then his second set was, I don't remember the numbers, but very much above the second set on the control day. This was after we cooled his- - Okay, so when is he doing the cooling? - He's sitting down and putting his hands in the

devices that we had built, which were cooling the palms of hands. - For how long does that cooling take? Can he do it inside of a three-minute rest period? - Yeah, that's what we were doing. We standardized the interval for resting or cooling to three minutes, okay. But the point is he got to his fifth set and all of the sets were above what he had done on the previous day. And he said, "I'm not tired. I can do another set." And then I can do another set. I can do another set. I can do another set. So from one day to two or three days later with cooling, he doubled the total work volume. He doubled the total number of dips. - By adding more sets and more repetitions to each set? - Right, so then he kept coming back for four more weeks, twice a week. And by the end of that month, he was doing 300 dips. - Wow. So what percent- - So he tripled. - He tripled. - Tripled, and so here is a professional athlete

00:45:35 Enhancing Recovery, Eliminating Soreness w/Intra-workout Cooling

at peak physical conditioning, and he triples what he can do. - Amazing, and in terms of his ability to recover, was that explored or discussed at all? Because my understanding is that if we cause enough stress to a muscle during anaerobic training, we provide the stimulus for compensatory regrowth, et cetera, but if we do more work, we essentially scale up the amount of recovery that's needed or the recovery time. I'm very curious about whether or not he needed longer to recover between these super-performing workouts? - That's very interesting. That was a major discovery, which we didn't realize we were making at the time. There is this phenomenon you're referring to as delayed onset muscle soreness, DOMS. And this is due to those little micro tears, and so forth, that are happening as we extend our workout capacity volume, okay? So we've had this experience so many times that an athlete or anyone will come in to the lab and they will exceed what their previous goals were, their previous expectations. And I can always see the words coming out of their mouth, "I'm going to be so sore tomorrow." They never are. - Interesting. - And we've actually demonstrated that with a naive group. We had a class, a physical conditioning class. And we had half of the, the first days of the class, we had to establish their true capacity, what they could do. So these were pretty heavy workouts for these new recruits. And we gave half of them the benefit of cooling and the other half not. And then we had them record their subjective levels of delayed onset muscle soreness. And those that were cool, didn't have significant muscle soreness. - Amazing, and I know there are also published results, and we will provide links to some

of these papers for people seeing similar effects, I should say, similar performance enhancing effects, using bench presses, the bench press, or pushups, or other sorts of things. Maybe you could give us an example from the realm of endurance work or aerobic work, running, cycling, things of that sort. - Well, one of the problems with, for us, is that our equipment now is not really portable. I mean, it's portable in the sense that you can carry it to the gym or to the football field. - But you're not going to run or run with it. - But you're not going to run with it, right. - Or equip a bicycle with it. Although when are the cooling handles on bicycles coming? - That would be good, but one itinerant activity is golfing. And people have put it on their golf carts, and- - Do people really heat up that much in golf? - They do. - Not to be disparaging of the golfers, but the way I conceptualize golf, it's like a swing and then a walk and then a cart ride and then a meal. I probably just offended all the golfers out there. - Well, one time we were doing work for the Department of Defense. And they wanted to check it out, whether or not what we were doing was really worthwhile. So they sent out a team of special ops soldiers to be our subjects and test it out. They were here for a week. So they that was a fun week. - Yeah, I do some work with those guys. They're hard driving guys. They also know how to have fun. But yeah, they definitely have, if they have an off or a quit switch, it's buried deep within their nervous system. They don't like to hit that quit switch. - So the guy who wrote the final report, he gave an addendum to the report and he said, "Well, I'll tell you this. After I've gotten home, it's added that technology," they took the technology with them. They wanted to keep it. - Oh, Yeah. That sounds about right. - And using it, it has added 20 yards to every club in my bag. And that's no effin' small deal. - Wow, so it's allowing people to hit further, hit their golf ball further? - Right. [chuckles] - Interesting. All right. So for the golf players out there, that's the reward you get back from Craig for all my little knocks on golf.

00:50:00 Multiple Sclerosis: Heat Sensitivity & Amelioration with Cooling

I don't have any knock on golf. I just don't think about it as a sport where heating up is a limiting factor. So since they're getting more out of their drive, what do you think's going on there? - Well, they can be heating up. - And they wear gloves, right? - They're wearing glove on a hot day, and so forth. But let me just tell you one more serious story about golfers and that is individuals with multiple sclerosis are exceedingly temperature-sensitive. - I didn't know that. - So they may still be mobile, but they have to stay in cool

locations and not increase their exercise to any great extent. But we've had subjects with multiple sclerosis who have just essentially put the device on their golf cart and they're back out playing golf in the middle of the summer. - Oh, that's great. - Yeah. - That's great. Anything that allows people to have normal levels of livelihood and recreation is great. We always think about performance at these kinds of like peak and elite levels and pushing harder, but yeah,

00:51:00 Enhancing Endurance with Proper Cooling

anything that allows people to be mobile and functional is great. So what's your favorite example of endurance, and feel free to give us the extreme one and then we'll talk about averages to make sure we're thorough about averages versus exceptions. - Right. We haven't done a lot in the field. I mean outdoors. Most of our endurance has been in a hot room with treadmill work, and so forth. So the very first experiment we had, I think, maybe 18 subjects just off the street. Maybe we just recruited people in the hallways, come on in and do this. And what we found is we could, for this group with one trial with and without cooling, we could double their endurance, walking on the treadmill, walking uphill on the treadmill in the heat, like maybe 40 degrees ambient temperature, 40 degrees centigrade. - So what does the experiment look like? You're having people walk on an incline. It's really warm. Some people are just going to hit the quit button and say, I've had enough and get off the treadmill with proper cooling. When are they doing the cooling? - They're doing it continuously. - I see. - Because in the laboratory, we can suspend devices from the ceiling, for example. Now we do have prototype wearable devices. We did them in response to emails from Ebola workers a number of years ago in Sierra Leone. They said, "We've read about your work with athletes. Can't you do something for us? I mean, we're in the personal protective gear, and we can't be in the hot zone for more than 15 or 20 minutes." So that was started us on the challenge of developing wearable systems that could go under the PPE. We've published that work now, but-. - That's great, and I'm guessing the military special operators that are out in the desert and other locations are probably excited about this technology. - Well, once they get it. - Once they get. It's coming, it's coming. Yeah, I think some people might wonder, if there are all these studies

00:53:00 Cool Mitt, Ice-Cold Is Too Cold, 3 Minutes Cooling

and there are these incredible results over the years on why haven't we heard more about it? And I will ask your opinion on that as well. But I'll just editorialize a little bit. Is that the best laboratory work in its practical applications oftentimes requires many studies. And oftentimes there isn't a portal, so to speak, to get that information out into the technology sector. So there is a company that's developing this technology for people to use, to purchase and use. You might as well just tell us now, what is the name of that company? And do they have a website? People are going to want to know where can they get this magical technology? And is there a poor man's version of it as well? - Well, the company is Arteria, A-R-T-E-R-I-A, and the website is www.coolmitt.com. So CoolMitt is just C-O-O-L-M-I-T-T. coolmitt.com - It's a great website. When I went there, it says that right now, the technology is only available to professional sports teams and military. Is that true? - Well, where we stand now is the new version of the technology is sort of in beta test versions. We got it into the hands of people who had used the technology before. So there's NFL teams that are using. There's college teams. There's Olympics. There's the Navy SEALs, Major League Baseball, the NBA, the National Tennis Association. They have locations where now they are trying this out and reporting back, how's it working? How could you change it? How could you improve it? And so forth. So that's where we are. But on the website, you can actually sign up for being one who will be able to get one [chuckles] when they are finally manufactured. They're now being made in fairly small lots, because you want to change things as you realize how it can be improved. - Yeah. This is Stanford after all. You want to get the technology right. I like to joke that one of the reasons I like being at Stanford so much is that, not only are my colleagues amazing and they're so forward thinking, but they're all perfectionists. And so that the perfectionist mindset is it has to be perfect before it can go live, so to speak. Well, I think there will be a lot of interest. Let's talk about the technology in a little more detail for a moment. And then let's talk about whether or not cruder forms of that technology exist either for sake of safety and/or performance. So what is, the CoolMitt, as I understand is it's a mitt, it's a glove. You put your hand into, you hold on to a surface. And that surface cools your hand and thereby through this specialized portal, cools your core body temperature and all the muscles of the body. Subjectively, if I were to do this right now, would I think that it was ice cold or would I think it was just cool? - Just cool. - I see. - Ice cold is too cold. So people always ask, well, why can't you just stick your hand in a bucket of ice water? It's too cold. What that does is that causes

reflex, a vasoconstriction of the very portals that you're trying to maximize the heat loss from. So you stick your hand in cold water, and when it comes out, it's cold. - You just sealed up all the heat in your body. - Yeah. Right, so what I sort of recommended to someone at one point, they said, "Well, when I'm running, can't I just carry a frozen juice can, and it will gradually melt?" And I said, "Well, no, because that's going to decrease the heat loss from that hand. But if every couple minutes you switched hands, [chuckles] it might work. - Well, I have a feeling that there are people now doing that as well as trying this. So how long, in the CoolMitt at the proper temperature, how long are people putting their hands into the Mitt? - We, once again, had just standardized them three minutes. And part of the reason for that is that the rate of heat loss is an exponentially declining curve, okay? And three minutes sort of gets the best part of the curve. So you can go longer and get more benefit, but the biggest bang for the buck is in the first two, three minutes. - Okay, you mentioned a number of impressive organizations, sports teams, and military that are using this. This is not something that I typically see on the sidelines of games. Although to be honest, I haven't looked very carefully. I'm guessing that they are probably keeping the technology somewhat under wraps. Where, and how are they doing this? Are they running back to the locker room? I mean, the military special operators are doing their thing, but in terms of the athletes, is it possible, hypothetically, that athletes are doing this somewhat incognito? - It's possible, but I really don't know. People have mentioned here at Stanford, they don't see the football team using it. Well, the football team here at Stanford is mostly playing in cold weather, cool weather. The night games are cool. Even day games are not very hot frequently here. But when they go to a hot place like Arizona or Utah, at least our coach,

00:58:20 How You Can Use Palmer Cooling to Enhance Performance

Shaw, says that they take it with them and that's when they find the benefit. That's when they use it. - Interesting, so is there a poor person's, poor man or woman's version of this? You mentioned the juice can passing back and forth. You mentioned cooling the hands. A number of people said to me after learning a little bit about this science and technology that they've experienced some big effects, positive effects of cooling by, and I confess, I've done this, taking a package of frozen blueberries, and just kind of passing it back and forth between my hands. Now talking to you, I realize I probably didn't do it long enough. I probably was, I was only doing maybe 30 seconds passing it back and

forth between my hands and then going back into sets. I did see a performance enhancing effect. Absolutely. But I realized I probably wasn't optimizing the protocol. If you were going to give a crude protocol for it, let's just say for the gym, because with running, it's a little bit tricky, but what would that look like if people wanted to just play with this in some sort of fashion? - Well, it would be experimental. - Sure. Yeah, none of that is very controlled. - Your idea of frozen peas is a good idea. And I think since there's been no actual study of that, it would have to be you working out what is the best for you. But one way to figure it out is that if, after you hold the cold peas in one hand and you switch it to the other hand, if someone then comes in, feels your hand, is it warm or cold? If it's cold, it means you vasoconstricted. If it's warm, it means the hot blood is still going there. Okay. So we do that in the lab. - And the key is for it to not vasoconstrict? - Right. - Okay. So there's a test out there, folks. If you're going to try this in kind of a crude fashion, at least until the CoolMitt is available more broadly to the general public, you want to assess whether or not your palms actually feel cool to the touch by somebody else. And if it does, that means you've essentially shut down the portal. You're sealing in more heat, which is bad. What about putting this cold pack of some sort on the face or - Or the feet? - Or the feet? I work out at home. I don't often work out barefooted, but I suppose I could, like they did in the 70s. When those guys were walking around without shoes and squatting without any shoes or socks on. Could I put my feet on them? - You could. If you simply had a water-profused pad and you were circulating cool water through it, you could just put your feet on it, okay?

01:01:15 Radiation, Convection, Heat-Transfer, Role of Surface Area

Part of the problem is that you don't want, if, let's say you have just a cold pack of something. The problem is back to boundary layers again. If you don't have a convective stream of the cooling medium, the heat sink is not as effective, because there'll be a boundary layer developed between the heat sink material and your skin. So that decreases its efficacy. - I see, maybe we should just for a moment, talk about convection, radiation, and convection, and just make that clear. Like if I put my hands, let's say it's a cold night and I'm at a campfire and I take my hands and I put them out to the fire- - You're getting radiation. - You're getting radiation. - Right. - Okay. - Right. - And then if it's a windy warm night, no, I don't know if that's the best example. Give us a good example of convection. - Convection, sure, is in a cool breeze. The wind chill

factor. That's due to convection, okay? But in terms of heat transfer between two objects, if you have convection of the medium, whether it's blood on the inside and water on the outside, you increase the heat exchange if you have convection on both sides. - Right, so this is why just planting my feet on two packages of frozen peas, my bare feet on two packages of frozen peas, there's really no opportunity for circulation of, and therefore heat transfer. So it's not really optimal, which, and I - But once again, it depends on the surface area to get any benefit at all. We have a study that we published, which was investigating the standard treatment for hyperthermia in the field. And the standard treatment, as recommended by medical organizations, is you take cold packs and you put them in the axilla, the groin. - The axilla or the armpit. - The armpits, the groin, which is - Thin-skinned, lots of vasculature. - Right, and the neck. So what we did is we did studies in which we made people hyperthermic. And then we measured the rate at which we cool call them by putting those positions in those heat exchange bags, in the recommended location versus on the glabrous skin versus palms, soles, and face. The cooling rate was double. - Wow. - And we put the same ice packs, the same cold packs on the heat portals, rather than the axilla, the groin and the face. - Wow. - Or the neck. - Wow, so face, hands and bottoms of feet will cool you twice as fast as putting cold packs into your armpits, your groin, or back of neck? - So I like to give the analogy of if your car is overheating, okay? And you have a hose, a garden hose, where should you spray your cooling system? Should you spray the radiator or should you spray the tubes going in and out of the radiator? Well, the rationale with putting these cold packs in the axilla, the groin, and the neck, is that you're getting close to the major arteries, okay? Sure. That's going to be effective. But it's much more effective if you actually increase the heat loss capacity of the radiating surface, the radiators.

01:04:40 Hypothermia Story, Ideal Re-Heating Strategy

- So you cool the hot stuff heading toward the core? - That's essentially what the standard operating procedure is. That you hit the arteries. - Amazing. - And the veins. Arteries and veins. - I'm going to just tell a brief story that illustrates how almost everybody gets this stuff wrong. And I'm going to use that as an opportunity to ask you about heating, deliberate heating, as opposed to deliberate cooling. So about four months ago, a friend of mine, incidentally, a guy who did nine years in the SEAL Teams, really skilled cold water swimmer. We went out for a swim in the morning. I'm not nearly

even close to the being in the same universe of his output potential. We do these swims. I'm familiar with them. I got enough blubber on me that I stay warm enough in the cold Pacific, no wetsuits. We do the morning cold swim for about a mile or so. And we brought with us up a young kid that I know real well that hangs out with us sometimes and trains with us who's got very little body fat. He's just exceptionally lean, despite eating everything in sight, right? Teenager, great athlete, great kid, great swimmer. So we're out there swimming and at some point we're talking to him and it's clear that he's gone hypothermic. He's slurring his words. He's not doing well. So we get him onto the beach. His teeth are turning yellow. He's quaking. His saliva is taken on that consistency that's clear, like he's hypothermic. We go to the lifeguard station. Lifeguard says, "Okay, let's get his vitals. Let's do all this." Meanwhile, trying stand next to him, and heat him up by heating up his torso. So there we are, pressing against this guy, our friend, trying to heat him up. They get a blanket on him. I'm realizing he was barefoot. His face was exposed. Although we did cover his head with the blanket. And he eventually came back. We got some warm liquids into him and he was okay. He was fine. I don't know whether his mother's ever going to let him swim with us again. If I ever disappear and go missing, it's because of that incident. Anyway, he did great. He recovered. He's back in the water and doing well. But I realized that pretty much everything from the point where we got back on the beach until he was back to normal, we did incorrectly. We heated his torso. We left his extremities exposed. And we assumed we were doing the right thing. And the lifeguard is a skilled lifeguard at a major public beach. So I guess the simple question is, did we get everything wrong? Did we get anything right? And what would have been the better option to heat up a hypothermic person in that, or similar situation? - Well, it's interesting you asked that, because that is the way we got into this area of investigation. I worked on how the hypothalamus regulates body temperature, neurophysiology. And one day we were having a discussion with a colleague in the department of anesthesia. And he jokingly said to my colleague, he said, "Yeah, you guys think you know so much about temperature. I bet you couldn't solve a problem we have in the recovery room." What's that? Well, the patient's come out of surgery. They're hypothermic and it takes us hours to get them to stop shivering. What do they do in the recovery room? Exactly what you suggested. They put on warm blankets, they put on heat lamps, and it takes them an hour or two hours to get these patients to stop shivering, to bring them back up. So we said, "Ah, it's a trivial problem." No. It's a hard problem. It's a hard problem, because when you're under anesthesia, you're vasodilated.

When you come out of anesthesia, you're hypothermic and you vasoconstrict, and that makes it very difficult to get heat into the body. So we got the idea that, well, if we could just take one appendage, like an arm, and we put it in a environment wrapped in a heating pad and a negative pressure, suction, that would pull more blood into that limb, that blood would get heated and it would warm the body up faster. So my colleague built a prototype device. You couldn't get such a device into the hospital these days. [Craig laughs] But we were with our anesthesiologist friend, we took it into the recovery room. And the first thing that patient said, "No way, you're not going to put that on my patient." But he prevailed and first patient didn't shiver at all, First patient was back to normal temperature, core temperature in, I think, it was eight minutes. - Amazing. - Eight or nine minutes. - Is this now standard practice in hospitals? - No. No, no. - So this is another example where, I don't get upset about the, although it's upsetting to know that it's not, but I think that it's yet another case where a fundamental problem exists. There's a science-based solution that makes sense at the level of physiology, engineering and practice, and yet it's not being done. - [Craig] Right. - And, I mean, that's a whole other discussion as to what the limitations are. Well, perhaps in, and I know a number of our listeners are in the healthcare and medical profession, as well as military, athletes, and just also standard other types of jobs, civilians doing other types of work. It would be wonderful if people understood this. So once again, is there a homegrown technology that people could use? If somebody is hypothermic, what is going to be the best way for them to warm up? Is it going to be holding a nice warm mug of cocoa or something like that? But not too hot, I guess, is again the idea. - Yeah, well, actually you can go hotter on the glabrous skin. - Oh, because it'll dilate? - Because it takes the heat away faster, okay? But back to the anesthesia, what you can do is you can use warm pads. They have them in all hospitals, they have circulating water, perfused pads. - Hot water bottle type stuff. - Put them on the feet. Put them on the feet. - So typically they'll slide them under your lower back or something like that? - Yeah, put them on the feet. Okay, sure. That will do it. But it turns out that we discovered through this work that it had nothing to do with the whole arm. It was only the hand. And that's when we came to the realization of these special blood vessels. We didn't discover the blood vessels that are described in "Grey's Anatomy," but nobody knew what they were for. - And you mentioned bears earlier and other hairy animals. Do they have these AVAs as well? - Oh, yeah. - And I suppose we haven't defined AVAs. We've been pretty good about the no acronyms rule. AVAs is?

01:11:40 Paw-Imer Cooling for Dog Health & Performance

- Arteriovenous anastomosis. So a connection between the arteries and the veins. Yeah.
- I actually used this technology. I have a bulldog, bulldog mastiff. He has a very high propensity for overheating, because they're terrible at dumping heat. And bulldogs are great at pushing themselves to the point of exhaustion or death. It happens, and so now we do what we call palmar cooling. Sorry, I couldn't help myself. Where I'll take Costello and lower him into a cool body of water. Just the bottoms of his paws, although I think animals instinctually know to do this and will go and stand in bodies of water. They don't often lie down all the way. Some do. But they seem to know that's a great way to cool themselves off. - Yeah. Oh, absolutely, yeah. - And they get the advantage that their palms and their feet are essentially the same thing. - We actually built devices for dogs. Did you really? - And tried them on. I did a lot of sled dogs and it worked beautifully. They had little backpacks with the equipment and pads

01:12:45 Warming Up, & Varying Temperature Around the Body

on all their feet and it worked beautifully. - Amazing, amazing, along the lines of heating, deliberate heating, wearing a knit cap is something that you see more of that on the East Coast: people run around Boston and New England with a knit cap. I've always done that at the start of my runs to try and warm up more quickly. And then I take it off. I shed layers as I go. Is that a rational practice? The way I just described it? - Oh, sure. Yeah. - Yeah? 'Cause warming up is important too. There's a certain amount of quote/unquote warming up that's required to lubricate joints or at least to get the sense that joints are lubricated and to be able to move more easily. - Yeah. - Do you still recommend that people warm up? - Yeah, but I think we're misled by the term warm up as if the major purpose is to raise temperature. I'm not aware of any data on this, but I do think that the major contribution is increasing flexibility. So you're going to avoid having damage of joints and tendons and ligaments and so forth. But also the ability of the mitochondria to produce energy can be impaired at lower temperatures. And you have to keep in mind that we say our body temperature's 37 degrees, but that's not true. - Yeah. It varies across the day. - Well, it varies in parts of your body. I mean, my hands and arms are not at 37 degrees right now. They're much lower, okay? [chuckles] - So that raises an

interesting question. What is the best way to measure core body temperature? - Well, the best core temperature is that, what we use is esophageal. So we put a thermocouple up the nose about two feet down the esophagus. So that is about the level of your heart. - Not gym or home-practical, although- - No. - I don't know. Some of those COVID swab tests go pretty far. I can't even imagine going any further. I felt like my brain was getting tickled. - The tympanic is pretty good. - So the ear? - The ear. It's not foolproof because you have to actually have it aimed properly at the tympanum and frequently what you're getting is you're getting sort of a mixture of tympanic plus ear canal temperature. - And for those listening and for those watching, the tympanic is not going to be the pinna, this part of the ear, the outer part of the ear. The tympanic is going to heading towards the tympanic membrane. And yes, I'm sticking my finger in my ear, because that's where the laser would actually have to go to measure your temperature. - Right. - So when we're walking into restaurants and other places nowadays, and they're shining the laser at our forehead, that's probably giving a pretty crude readout of temperature. - It is, but there's much less insulation between your brain and your forehead skin than there is between your biceps and your arm skin. So if you're going to measure a surface temperature, that's where you would do it. And we do temperatures in the infrared. We take infrared videos of athletes and our subjects. And of course the face lights up. - Okay, so if we're not, I imagine there's going to be a technology coming soon where you can point your smartwatch or your smartphone at yourself, and you're going to get a heat map. - Right, right. - If somebody out there hasn't already invented this for the typical folks outside military, somebody please invent that, because I think there's growing interest in temperature based on the work that you're doing. And also for sake of something I do want to touch on, which is sleep and metabolism. Although we don't want to open up those portals all the way, because we'd need several days to cover it. Okay, so putting on the cap, what about some of the helmets and gloves that are used in typical sports? Do you think that those can be improved in order to improve performance in terms of their ventilation ability or keeping palmar surfaces open for instance? - Well, you mentioned about the knit cap in cold weather, especially, and that is significant, because you do lose a lot of heat from your head, but it's a constant heat loss. It's not variable like your glabrous skin. So if you decrease that heat loss, you're going to be warmer. So, sure. That has an impact. Now in terms of helmets, they should be ventilated. I mean, they should have enough space in them and holes in them so that air can circulate. You don't want to insulate, thermally insulate your scalp. That's going to decrease heat loss

quite considerable. Just for a resting individual, the brain is about 20% of your metabolism.

01:17:35 Cooling-Enhanced Performance Is Permanent

So that's a lot of heat production. - Yeah, absolutely, I realized there was a question that I failed to ask earlier that is burning in my mind now. And I think is likely burning in the minds of some of the listeners, which is, so if you do this cooling in between sets in the gym, you get this performance enhancing effect. You don't get the delayed onset muscle soreness, which is great. So presumably the body is adapting. You're getting better as a consequence of being able to do more work per unit time or to go harder in some way of course. You get that adaptation. Does that mean that you see a performance-enhancing effect, even when you don't cool, if you've previously done the cooling workouts? So for instance, let's say I can do 10 sets of 10 dips, which I like to think I can. But maybe I need to go try. I dunno if I've done that recently. I do the cooling. I cool for three minutes between sets. And let's say I get to the point where I can do 20 for 10 sets, 10 sets of 20 repetitions. And then I don't cool. Will I be able to match or approximate my new, better performance? - You keep your gains. It's a true conditioning effect. You respond to the increased work volume by all of those mechanisms you mentioned. - [Andrew] Amazing. - You increase the number of contractual elements in your muscles. - Amazing. - The muscles get bigger. - Amazing. - We had an experiment that involved some of our female students. Not athletes, but just regular, they were freshmen actually. And the experiment was 10 sets of pushups to muscle failure with or without cooling. - Same regimen, three minutes of cooling in between sets of pushups? - Right. - Okay. - Some of those young ladies reached over 800 pushups. - Now the total duration of the workout could be getting much longer as a consequence of doing more work. - No. - No, it doesn't take you longer. Well, minor, I mean, a push-up is pretty fast. - Yeah. It's pretty fast. - Yeah. So you do 10 sets, the maximum 45 minutes total. The most- - That's a lot of pushups. - That's a lot of pushups. - Yep. - And so the interesting thing is they came in one day and they said, "Dr. Heller, you cost us a lot of money." "Why?" "Well, we had a formal dance this weekend. We all had to buy new sleeveless dresses."

01:19:55 Anabolic Steroids versus Palmer Cooling

- Nice. [Craig laughs] It's a good problem to have. Good problem to have. Let's talk about steroids, anabolic steroids. We're heading into an Olympics. Every time the Olympics rolls around, you hear about these cases of people getting popped, as they call it, or caught for anabolic steroids. There are some accusations out there. Now they'll be out more. This'll get handled in the press and in the various organizations. Clearly athletes and non-athletes use anabolic steroids. And typically anabolic steroids are of the testosterone variety. There are derivatives, et cetera. And those derivatives do different things in the anabolic versus androgenic, et cetera. But typically the idea is, at least as I understand it, in talking to some of these individuals, is that they allow people to train more, because they recover faster. They are able to synthesize more protein, because they're basically getting a second puberty, because as we all know during puberty, there's a lot of growth of the body. And of course there are a lot of negative effects of abuse of these things and they are banned from various sports organizations, especially, I should mention, in combat sports, it's especially concerning, because in combat sports, a performance enhancement means that you can harm somebody more than you would be able to otherwise as opposed to in other sorts of sports. Just to conceptualize it. And I'm not taking a moral stance on any of this. I just want to ask you, when you compare palmar cooling to anabolic steroids in terms of gym performance, what do you see? - Well, we do not do research on steroids, [chuckles] but there is a lot of research in the literature. A lot of that research in the strength conditioning magazines is not very scientific. - No. - Okay? - Or it might not even be scientific at all. - Right. - Right. - But we did do an analysis of reputable papers and we did find, I think it was probably eight or nine, 10 studies on bench press, increase in bench press performance on steroids or not, okay? - These were males or females? - Well, these were all males, but I'll get back to the females, okay? The bottom line is that in all of these independent studies, their rate of improvement was approximately 1% per week. - Okay. - Okay? Now I've just told you about studies in which we've had 300% increase in a month. [Craig chuckles] So. - It's an enormous, enormous difference. - So why would you endanger your health as well as your legal ability to compete with such an ineffective tool? - Yeah, no, I think it's the notion of performance enhancement is a really interesting one, because people clearly pay attention to nutrition. Sleep is now something that I think everybody, but especially athletes are paying attention to. - Right. - And I predict that temperature will be one of the more powerful parameters that people are going to be focusing on. - Yeah. That's true. - Because of the magnitude of the effects that you're

describing and also because so much of the variability around performance, as you mentioned, has to do with when you go to a new environment, everyone has their home environment worked out pretty well. Sleep well in your own bed at home. When you can control everything, your performance is always great. This is why I think military special operators are particularly interesting group, because their whole world is centered around elite and high performance with very high risk,

01:24:00 Female Athletic Performance

high consequence under variable conditions. The essence of their work is variable unpredictable conditions. So you mentioned female athletes and steroids. I'm curious about this. - Yeah, because everybody has always said to us, well, you only use male subjects and obviously they have this testosterone background. They have higher levels of testosterone. That's why you get these results. So we did a comparative study on females. We get the same results. - Impressive, and these are Stanford athletes or also-
- No, these were not Stanford athlete, they were Stanford students. But not athletes. Well, we have done, of course, work on some athletes. But in general, we don't do research on our teams, our varsity teams. So they have their own protocols. They have their own training program. - Yeah. They don't like us to get too close to them. I work with some of these folks in the coaches and they are very skeptical, with good reason also. And the reason I ask is that when you see these Pac-10 or Division I college athletes, and then you see their peers, there's clearly a difference, right? I mean, they are pedigreed at throughout, right? And more typical folks also have different goals. They may not want to get infinitely stronger

01:25:18 Shivering & Cold, Metabolism

or perform more endurance work. So I want to ask you a couple of things about shivering and metabolism, 'cause I think they're very interesting and sufficiently related. So my understanding is that shiver is an adaptation that's designed to heat us up. - Yes.
- That we have brown fat that's in compartments around our body that are activated by shiver or co-activated by shiver. And that shivering is useful for increasing metabolism. Is that true? And does it require that cold be the stimulus? So two scenarios. I'll give you an experiment. I put someone into cold water of some sort, and then I make them get

out or I have them stand near it, and then they start shivering. My understanding is that their metabolism will increase. What if I take someone and I just have them shiver, but they're not exposed by cold, it's kind of a deliberate shivering. Will that also create a substantial increase in metabolism? - Sure, so deliberate shivering without cold is essentially what happens when you get a fever. Your set point goes up in your hypothalamus and you actually, even though you're a normal body temperature, your thermostat is telling you you're too cold, increase your metabolism. So shiver, right? So, sure, shivering is a good way of increasing metabolism, but it only can take metabolism up maybe three or four times resting. - Okay, but it seems like- - Whereas exercise can take you up 10 times. - Got it. All right. I'm going to ask a couple of more random questions

01:26:55 Studies of Bears & Hibernation, Brown Fat

and seemingly random. Do bears actually hibernate? - Oh, yeah. - The true hibernation? - Well, it depends on how you define true. A bear, actually, we've done a lot of work on bears. [Craig chuckles] - Do you also put the nose thermal couple down in the esophagus? - We implant them surgically. - They're anesthetized when you implant them? - Yes. - What kind of bears are these? - Black bears. - Okay. - And did this with colleagues at University of Alaska. And we're analyzing the data now, but what we've done is we've had now a total of 18 bears and we implant them with EEG, EKG, temperature sensors, and sometimes we actually measure their oxygen consumption. - These are bears in the wild? - These are bears in the wild, but they're brought in to University of Alaska where we keep them in an outdoor enclosure. So they're hibernating in a nest box in an enclosure, and we're recording this electrophysiological data continuously for six months. - Amazing. How do I get on this protocol? [Craig chuckles] [Andrew chuckling] Craig and I are doing some work together going forward. And maybe you can slide me onto this protocol too, it sounds amazing. - Right now, it's a matter of just analyzing the gigabytes, terabytes of data that have been collected. But anyway, you asked about hibernation. So bears only go down to about 33, 34 degrees centigrade in core temperature. And that's been argued that, well, they can't go lower because they have so much insulation. They're so big, their surface volume ratio, and so forth, and that's not true. They shiver, so if we have a day like a minus 40, which you get up in Alaska, they will go through periods of shivering. And maintain a core temperature on

33-34. Now the ground squirrels and the marmots, which are smaller animals, they will drop down to a body temperature maybe within a degree of the environment. So they can go down to one or two degrees centigrade just above freezing during bouts of hibernation. So they'll stay in hibernation for seven or eight days and they'll come back up to normal body temperature for a day, then they'll go back down, and do another about- - What do they do during that day when they're warming up again? Do go around- - They rearrange their nests, eat, if they've stored food. Some species store lots of food. Others just depend on their fat. - A former mentor of mine, my master's degree mentor, and a colleague and friend of yours, Irving Zucker at UC Berkeley told me a story once, told me a lot of stories, he tells great stories, as you know. He told me that when an animal comes out of hibernation periodically, that it's a very dramatic thing to observe. That it's not like they wake up and yawn and look around, but it's like a complete epileptic seizure. - Right. - What what's going on? - Shiver. - It's just a very traumatic shiver. - So at the low temperatures, they cannot shiver because the effect of temperature on the conduction of the nerves and the muscle fiber. - So they're shut down basically? - They're shut down. So there they use brown fat. So they activate brown fat and then when they get up to a temperature of maybe 15, 16 degrees centigrade, then the shivering starts and it gets very, very violent, but they're still asleep. - Do we shiver in our sleep? - I would imagine we do, but it probably wakes us up. - Interesting, So the brown fat is kind of like kindling? - The brown fat is a tissue which has lots of stored energy, 'cause it's fat, but unlike our white fat, our regular fat, it also has lots of these little powerhouses, mitochondria, and lots of blood supply. So essentially it is a tissue just to produce heat. That's what it's there for. Now in these hibernators, there are big patches of brown fat at certain locations that are critical, like around the heart, for example. For us, the brown fat is sort of distributed. So for many, many years, it was thought humans don't have brown fat, but indeed we do. It's just not localized into discrete fat pads, like it is in ground squirrels, marmots. - I don't know why the phrase fat pads is so satisfying

01:31:10 Brown Fat Distribution & Activation In Humans

to say, but it is fat pads. Speaking of fat pads, I was taught that we have, by the internet, I should say, I was taught by the internet that we have brown fat between our scapulae and our upper neck. Is that truly a source of brown enrichment for brown fat? - If you're a

ground squirrel. [Andrew scoffs] - So this is all the drawings out there? Okay, so what I'm hearing you say is that brown fat is actually distributed in patch- - In humans, it's distributed along with other fat tissue. It's not as discreet. - So the reason I'm kind of shocked and amused and troubled by this is because there is a somewhat standard protocol in the performance, wellness, whatever world, whatever you want to call it, of putting ice packs on the upper back as a way to stimulate brown fat thermogenesis. I'm hearing some inhales of concern from the physiologist. So tell me why, it sounds like that's probably not the best way to stimulate brown fat activation. - Well, let's put it this way- You're not attacking anyone specifically, because the whole little believes this. - But it may not be totally facetiae or false. Think of what that's doing. If you put ice right there where your spinal cord is close to the surface, that's where you're going to hit the vertebral arteries. So you're essentially putting a cold source into the brain, to the hypothalamus. The hypothalamus is you're too cold. So it is going to turn on shivering and brown fat so. - Would there be a better site for sake of activating brown fat? Palmar cooling? - I can't say because the activation of brown fat is a sympathetic nervous system response. So any lowering of core temperature that will let the thermostat say you're too cold is going to turn on sympathetic. Now people will have perhaps different amounts of brown fat. So newborn have more brown fat than adults. - 'Cause the newborns can't shiver. Correct? - I don't know. - Okay. That's what I read. I don't know if that's true. I read that in what I believe to be credible sources. - Yeah, it could be. I just don't know, it depends on if it's really newborn, I can agree because you don't have all of the motor pathways connected up yet. That's something that occurs in early days of life and is probably one of the functions of REM sleep, which infants have a lot of. - Right. - Okay. But how to activate brown fat if you are consistently exposed to cold? So if you live in the Arctic and you go out jogging in the winter, maybe that will increase the amount of brown fat you have. If you live in the tropics, maybe you have less brown fat.

01:34:18 Brain Freeze, Ice Headache: Blood Pressure, Headache

I don't know. I don't know of any studies which have looked into that. - Okay. Ice headache. Sometimes I'll drink a cold beverage or I'll eat ice cream in my head will- - Brain freeze. - Brain freeze. And speaking of special forces, I was talking to, we all see the images of the SEALs, SEAL training slash screening in Coronado where they're going in and out of the Pacific, which is very cold. But I know they also spend some time

in the very cold waters of Kodiak, Alaska. You mentioned Alaska. Brain freeze, so-called ice headache, is a common occurrence there in those situations. But we all have experienced this. We eat ice cream, and you get that brain freeze. I can feel it right now a little bit subjectively. I can induce it. What's going on there? And I would always just rub my tongue on the roof of my mouth. Is there something that I'm doing that's functional there just to try and alleviate it? - Good question, the thing is that the roof of your mouth is very close to your hypothalamus. So if indeed it's a Popsicle that's giving you the brain freeze, it may be a direct cooling effect from the roof of your mouth and if you put your tongue there, you're insulating the roof of your mouth. I don't know, I'm guessing. - But what's the source of the brain freeze? It at vasoconstriction? - It's a vasomotor change. Whether it's constriction, I think it's more likely an increase in blood pressure, which will essentially cause an expansion of the arteries and activate pain receptors. We don't have pain receptors in the neural tissue in the brain. We have them in the meninges and predominantly associated with the blood vessels, the walls of the blood vessels. So if you have something which will dramatically increase your blood pressure going to the brain, you're likely to get... We've had some preliminary data. I even hate to mention this, because we have not been able to pursue it systematically, but we've had some experience with people with migraine that say, if they use one of our devices to heat, that the migraine goes away. And I don't know. - Yeah. It's very, and a lot of people suffer from migraine. I know there are a lot of different types of migraine. I've been reading a lot about this lately, because I get so many questions about migraine but. - I'd hate to say anything. - Sure. And we'll just underscore this as preliminary and people have been great about understanding that when we say preliminary, we mean it has not passed through the required filters to call it hard fact yet. - We don't even have a decent dataset. These are anecdotal report. - Yeah, anecdata, as people like to call it, but I don't even like to call it that because we don't want to give it more weight than it deserves, but that's interesting. The ice headache and the increase in blood pressure is interesting because the only thing that I've heard is similar to it is something that comes from, they have these competitions where people eat these very hot chili peppers. It's kind of an ego thing, I guess, for reasons that escaped me, that eating really hot peppers. And every once in a while, someone will eat one of these and get what's called thunderclap headache, where a headache comes on extremely quickly and so quickly that it's caused, so severe rather that it's been known to cause stroke and brain damage.

01:37:50 Fidgeters, Non-Exercise Induced Thermogenesis

So these very, very hot peppers, if you're not acclimated to them, and maybe even if you are, have been shown to actually cause brain damage. Yeah. Some good evidence for this. I do want to talk about something that we have not touched on yet, which is NEAT. Non-exercise induced thermogenesis, right? So non-activity associated thermogenesis. And the fidgeters, right? So the classic work of like Rothwell and Stock. And the idea that some people who overeat are burning off that energy by way of shaking their knee or moving around a lot. The quote/unquote nervous types. But they quoted in those studies, a huge degree of caloric burn, 800, 2500 calories per day burned above those who sit rather still. Does that seem farfetched? Those are older data but any comment on NEAT or non-exercise induced thermogenesis? - Well, I do think it's pretty straightforward that if you increase muscle activity of any kind, you're increasing your energy consumption and your heat production. And the really extreme example is hyper and hypothyroidism. People that are hyperthyroid or fidgety and they have a high metabolic rate and they're hot. And people that are hypothermic are cool. They don't move very much. So any kind of muscle activity increases, and when you say it's not much activity, but remember it's only 20% effective. 80% of the energy is going to heat. So it may not exert much energy to tap your foot. [chuckles] But four times the amount of energy that is going into the movement is being lost as heat.

01:39:44 How Pre-Workout Drinks, & Caffeine May Inhibit Performance

- That's very interesting. A couple more quick questions. There's a lot of excitement these days or at least usage these days of so-called energy drinks or pre-workout drinks. Many of these contain thermogenic compounds. So caffeine, things, there's a culture now of taking arginine, things that support arginine. So beet juice and L-citrulline, things to dilate the blood vessels. Sometimes this is for sake of increasing blood flow to the muscles during resistance exercise. But a lot of these are thermogenic, is to increase body temperature. And is it possible that some of these energy drinks are actually, or similar, six espresso or whatever it is, are acting to prevent optimal performance or reduce performance? - I don't think that the temperature rise is that, I really don't know, but what it does is it makes you more jittery and you're going to increase that NEAT that you were talking about. There's another thing. And that is that when you are exercising

your muscle and it becomes slightly hypoxic, I mean the oxygen suppliers is not enough, the muscle releases adenosine. And what adenosine does in the muscle is cause the blood vessels to open up, to dilate. So it's a way of increasing the blood flow to the muscle and therefore the oxygen supply to the muscle. - And caffeine is essentially an adenosine antagonists. - An adenosine antagonist. Right. - So under the strict logic, ingesting caffeine will reduce adenosine release and will reduce oxygen utilization of the muscle? - Right. - So that would lead me to believe that, motivational support aside, that caffeine will hinder muscular performance? - I would think so, but I can't give you an authoritative answer on that. - Okay, we're just going through the logic and the gymnastics around that. I think it's a fascinating area that deserves attention because the question of what one can ingest in order to perform better, to say nothing of hormone augmentation, but often leads back to stimulants. And if those stimulants, most of which include caffeine of some sort, are inhibiting the adenosine system and the adenosine system is supporting the oxygenation of muscle, then I would imagine that avoiding them might be the better option. - Yeah, I just, I'm not aware of data that would, so this is a general phenomenon of adenosine and blood flow. It has of course, a different effect in the brain. Adenosine causes sleep. So caffeine keeps you awake. And if you stay awake, you're going to have a higher metabolic rate than if you go to sleep. And the thing is you say, energy drinks, the question is, what really is in them? - It's usually a cocktail of things. I don't take these, I don't like them at all, but they're usually a combination of vasodilators, caffeine, some sort of stimulant. - And source of glucose usually. - Sometimes a source of glucose and sometimes not. And oftentimes there are vasodilators and there are compounds that are thought to be so-called nootropics, smart drugs that basically increase acetylcholine or norepinephrine transmission. In the 80s and 90s, the beta-3 agonist like clenbuterol were very popular, but they were all banned. So those were all banned from, although people used them recreationally, which I do not recommend.

01:43:42 Sleep, Cold, Warm Baths, Screens, & Socks

There were actually a number of deaths due to dehydration, overheating, as well as cardiac effects. Before we wrap up, I know you've done a ton of work on sleep. I think we're going to have to do another episode about your work on sleep, because the amount of data that you produce there is vast actually. So I first got to know you and

your work related to sleep and temperature. We all hear nowadays that it's good to keep the room that you sleep in cool. Keep it dark. I've talked a number of times on podcast episodes about the role of light and shifting circadian rhythms. I have two questions related to sleep. One is, are there any things that may or may not relate to temperature, but that you think are very useful for getting better sleep, that you don't hear that much about, that people might want to consider or try? Realizing that there are a lot of reasons why people don't sleep great, but what are some things that you don't hear that much about these days that you wish people knew? - Well, the sleep medicine community now puts a lot more emphasis on cognitive behavioral therapy than on pharmacology. So what cognitive behavioral therapy does is it essentially increases your sleep hygiene. So there are certain just general rules. So have a regular bedtime and a regular arousal time. Don't be skipping back and forth all the time. - Arousal, you mean wake-up time? - Wake-up time, yeah. - Spoken like a true physiologist. - Right. [laughs] Yeah, another thing is don't use screens within a couple hours of bedtime, because screens are predominantly rich in blue light. And what that does, as you mentioned, the circadian system, that affects your circadian system. That pushes off your circadian stimulus for sleep, okay? Another thing is of course relax. I mean, don't work right up until the time you're going to bed. Take some time to do something relaxing. And then temperature, you've mentioned that. And for many people, a warm bath is really conducive to good sleep. And people are now swearing by a cooler environment for sleep. And that makes sense in terms of the circadian effect on body temperature. So our circadian clock is effecting our thermostat. So at the time we go to bed, our thermostat is on its way down to a lower set point, okay? So what happens? You go to bed and you're feeling a little bit cool. So you pile on lots of blankets. And then what happens is you wake up a little bit later and you're hot, so you throw them off. It's because your thermostat has set downward. Now why is it better to have a cooler environment? It's better to have a cooler environment, because it's easier to thermoregulate. So you can go to Europe in the summertime and the hotel rooms still have these big comforters, these down comforters. So how do you deal with that? You stick out your hands and your legs, okay? - I've always slept with, I have one leg that just kind a hangs out of the, yeah. - But they're your heat loss surfaces, right? So if you're in a cool environment, you can take advantage of that. You can take advantage by passively regulating your body temperature. You don't have to get up and wake up and say, oh my God, I've got to change the covers or blankets, or what have you. If you're in a warm environment, what

can you do? - You need to sleep with one hand in the CoolMitt. - Right. - Right? And right now that's not available yet. - Right. It's not available. - I've never heard about it that way. I've always heard you want to sleep in a cool room or keep the room cold. - Yeah. - But I never realized why that's useful, which is, you're saying, then you can move these glabrous surfaces in and out. You could even also wake up under the blanket completely. - Your face. Yeah, yeah. - Very, very interesting. That finally a rational science grounded explanation for why we need to sleep in a cool room. 'Cause I always thought, well, if your temperature is going down anyway, why do you have to sleep in a cool room? What about wearing socks while you sleep? That was big a few years ago where they said, you should put socks on. Now I would think that's probably the wrong advice. You probably just- - Well, I don't know if it's wrong advice. There's an old, old study that was supported by, I think, Eddie Bauer, the sleeping bag company. And what the study showed, what the study was asking is what are the most temperature-sensitive spots in the body? Where do you feel cold? And what that showed was it was the toes. - That makes sense. So when you sample water with your toe, you always see that. [Craig laughs] - So the socks essentially are promoting thermal comfort by insulating that area that's quite sensitive.

01:48:44 Synthesis

Now of course, if it's too warm, you're not going to put socks on. - Right, well, Craig, thank you so much. You gave so much information that's actionable and interesting. I know a lot of people are going to be really interested in the palmar cooling technology from CoolMitt. We will be sure to provide resources to the website so that people can register interest. I do encourage people to play around with, so to speak, the palmar cooling technology that we all have, which are these glabrous surfaces. And I also just want to thank you for taking time out of your busy schedule to share this information. - Yeah, you're welcome. It was fun. It was lots of fun. - I certainly learned a lot and I know a lot of people are going to learn a lot that's useful to them.

01:49:30 Supporting the Podcast & Scientific Research

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