DANNY LENNON: Hey Trent! Welcome to Sigma Nutrition Radio. Thank you so much for taking the time out to come to the show today.

TRENT STELLINGWERFF: Yes, thank you for having me here Danny.

DANNY LENNON: It's been a conversation I've been hoping to have for quite a while and really like I mentioned to you looking out performance nutrition for the high-end endurance athlete specifically isn't something that has been really addressed in that grade of detail on the show yet. So, I think it's going to be a really, valuable episode. And before we get into any of that stuff, just for those of people that are listening right now, maybe give them a bit of context of your background, your career and academia to this day and really the work that you do right now, what are that comprises of.

TRENT STELLINGWERFF: Sure! I can try to do that quick. Ok, I was a decent athletics athlete so I had a scholarship to the U.S. athletics at Cornell University and then I'm Canadian. I went back to Canada and then my PhD at the University of Guelph which is just outside the Toronto with Professor Lawrence Spriet. And Lawrence is a Guru in caffeine but also a Guru in muscle metabolism. So, my PhD involves muscle vibes, he's in

blood draws and AV lines and it was quite mechanistic but it involved nutritional interventions.

At that point, we collaborated a bit with the Australian Institute of Sports and Louise Burke's group with some of their high fat adaptation studies where they send us over muscle samples and we did the analysis in the lab. From there I went and change a little bit and did protein work with Luc van Loon in Maastricht, Netherlands for just over a year. My wife and I moved over to Europe for six years and then from there went down to Lausanne, Switzerland where I was the Director of Research for power bar for about 5 years. Throughout that time my wife set a two-time Olympian in athletics 1500 and being base in Europe was ideal for both of us and then in 2011 we moved back to Canada and where I'm now base at the Canadian Sport Institute Pacific based in Victoria British Columbia. And so, I worked at a Olympic Training Center but I'm adjunct at University of Victoria and University of British Columbia. And so, part of my job is working in the trenches with our Canadian Track and Field team as well as with triathlon and a bit with cycling.

Formerly, I did a lot of work with rowing and part of my job is innovation and research. So, I'm kind of straddle between the applied practical world of working with our Olympians versus the academic world of applied research, so. Sorry for that long answer, I've been a bit of a journey so that's kind of where I am, am at now.

DANNY LENNON: Yes, that's a perfect answer and I think it ties in perfectly that you ended up highlighting the kind of ---being able to crossover into both your work with elite athletes and practical level of implementing this stuff in the real world and also your journey in academia and of course when you mentioned some of those names in research and those institutes that you mentioned, people who are within sports nutrition health research will know immediately how prestigious a lot of that is and obviously with the elite level athletes that you worked with I think that gives an incite that maybe not many others can give because really, when we're talking about athletes at that higher level, some of the

what we might think are norms of physiology kind of caught off the window almost right?

TRENT STELLINGWERFF: Oh yes, I can a--- when I started working at Rowing Canada, I've been really honored and blessed to work with endurance athletes but not endurance athletes to that size. And I remember where this doing some basic physiology and it's the first time I measured a VO2 Max of over seven leaders' absolute and I certainly dropped a few four-letter words in the lab and I was so impressed like two or three of the guys had 7 litter plus VO2 Maxs and at that time, our mandate has set the world record of 519. It just got beaten in the weekend in fact, by the Germans 518 but it was pretty interesting time to have work with such pedigree and such thoroughbreds in that group. So, you do see extreme things and working in extreme area and elite sports is extreme if you think you can win a medal, you have to be willing to strategically risk taker at times and that's kind of a world that I'm most versed in.

DANNY LENNON: Yes, and maybe before we get into some specifics around nutrition strategies just what we're talking about athletes, some of the triggered of my head the other day, I think you actually put out a tweet as since you're talking about the issues that can crop up when we're trying to take research and statistics that are done in certain studies and see how they're going to apply when we're looking at elite athletes purely because just how few people are truly elite. And so, with that kind of concept in mind, how do you--- what is your overall philosophy on how we can best have evidence based practice but how do you use that when you have elite athletes who are just purely, genetically the elite of the elite?

TRENT STELLINGWERFF: Yes, well you hit the definition of the elite means it's very few of them, so you have very small subject pools. Secondly, when you're extremely elite, you're much more closer to the genetic or biological ceiling of optimal or optimized individual performance. So, when you do an intervention you're effect size is going to be a lot smaller, and you can go through and look at various method analysis and with a tease out or the look at effects sizes of say sodium bicarbo caffeine and the look at wild trained versus untrained and

the untrained subjects always have greater effect sizes because they're just more head room to move into. And then finally, you know on the elite level, a difference of 2% can be massive, it can be the difference of being ranked say 10th in the world versus the 150th in the world and trying to measure something a performance intervention of the lab 2% or less is incredibly—incredibly tricky. The rather approaches to statistics to try and handle that and look at that in terms of corn effect sizes or magnitude based differences but I'm not a statistician.

I don't really want to go down that road because there's controversy on whether those are appropriate as well. A recent paper few years ago at the Australian Institute Sport and their statisticians challenged that approach too, so we're stuck between a rock and a hard place at times, but it's a---I use a framework where you know on the lowest level of it, evidence is just anecdotal evidence and then you move up to something like once clinical trial or an intervention trial, and then you might get you know to multiple studies that have shown an effect. I do in the least semi elite population then you might get to meta-analysis but for me the highest grade of evidence is individual collected data on the athletes that you're working with.

And so, the publish data hopefully supports the trend analysis because it is just a trend analysis of what you see in your athletes. And if you collect data rigorously enough in terms of you know if we ever a rower is coming in to do a 2k task and we're going to try some different supplements and they're going to do 6 2k test over the year, and we can create a standardized taper and standardized---semi standardized condition. We can learn a lot from them individually on what works to adopt and individualized, so for me the highest level of evidence is individualized trend analysis, trend data in the athletes that you were working with that is then back supported by similar types of findings in the literature but it's--- it's not clear cut.

DANNY LENNON: Yes, for sure and so if we turn to maybe thinking about some general principles for fueling the training workload that many of these endurance athletes would have and I'm

sure there's plenty of people listening who are involve in those various different sports. Just from a kind of overview level because obviously we can talk about these specifics for one given person. What are the factors that the athlete or the coach need to consider in order to even start the process of an effective nutritional programming when it comes to, okay this is what my workload going to look like, how am I going to best fuel, what are the things that I need to be thinking through from the out--- or what's the good starting point or even for us in this conversation?

TRENT STELLINGWERFF: Yes, so I respect a bunch of the work that James Morton and Graeme Close and their group is pushing on ahead on a recent review what part of the title talking about Fueling for the work required and I think that is a great spot to start but it is also an incredibly a complex spot to start because the concept of fuel metabolism during training or during various sports gets incredibly complex. There are decent estimates of that, but that said and you---excuse me and you can back estimate off a heart rates, out of wattage meters but a lot of that stuff works really well during steady sate, but if you do an interval training, you know longer and steady state, there's excess post oxygen (EPOC), post oxygen consumption considerations. You know if you actually watch a gymnast for 2 or 3-hour practice and you start a start & stop watch every time she does something. They actually work that a gymnast does is incredibly small and very explosive but there's along and very long lag times between various elements and various parts of practices. So, first and foremost you as a practitioner need to get in the field with the athletes and the coaches and there's a couple of things. One, you can fully appreciate what the athletes is going through, what their environment is like, is it hot, is it cold, what time of the day is it, what are the limitations they're on feeling at that of the day. For a rower, it is 6:30 a.m. practice, you know what practically is there issues there. When they come of the water how long does it take to get food, could you supply food when they come off the water, how much can you fuel in a two and a half hour-practice like practically. Are they rowing the whole time? Because it's hard to do a drink bottle when you are pulling

an oar. That's just one sport context. And the second thing that does is it, it earns credibility and it earns trust and it earns slowly, slowly earns buy-in, but and if you come to practice and hanging out at 6:30 in the morning out on the coach boat in the rain or the cold weather or the warm weather. And so usually that is where it all starts is really truly look at the demands, try to back estimate what some of the caloric needs are, try to get in into the literature to look at what the macronutrient profile of that sport is. For example, if you're a tour cyclist there are indeed long stretches of training where your heart rate might be under, under a hundred beats per minute. And there's a high contribution of fat oxidation. If you're a marathon runner, even your easiest of easiest run are still done at about 75 to 80% of fat--- or carbohydrate oxidation. So conversely because you can't soft pedal when you run. Like running is always quite metabolically costly in terms of calories but also in terms of carbohydrate oxidation. So, it's just really important that you take the time to understand the demands because then if you're going to be making recommendations in that context with that athlete in their environment, you could go wrong very quickly if you don't understand the basics.

DANNY LENNON: Yes, I think that is such an important point of knowing those kinds of metabolic demands specially from a practitioner's point of view of having some understanding of nutrient metabolism that's going on. So, that like you say once we can do that, now you're in a much better position to understand why you're given certain macronutrients recommendations etc., etc. With that in mind, obviously within the past few years, there's been lots of different trends that have popped up and some of them have started to seep into sports nutrition or at least some athletes dabbling with them certain different level of the sport. Is there anything outside of-–sort of we take on one hand conventionally the way an athlete would fuel for say--- say we have a marathoner or triathlete and typically what in the past they've been done to fuel that event. Is there anything that on one hand you see a merging either from what you're dealing with athletes or that's emerging from the literature

that might be a bit different to what is conventionally been used or at least something for athletes to explore and then maybe on the other end, do you think they're starting to be practices used and or new practices used that are maybe potentially detrimental to athletes?

TRENT STELLINGWERFF: My next few comments I guess just to be really clear, I think that there's need to be a different philosophical approaches to fueling training and workloads versus fueling the actual race competition and so my next comments are going to do exclusively with fueling during a race situation. I presented on this actually just a few weeks ago at American Colleges Sports Medicine of Energetics in fueling in competition situation and like I said you know few minutes ago, the vast majority of Olympic sports are very carbohydrate dependent and during competition, carbohydrate dependency will fuel performance. I, I---and last, there's an avalanche of unpublished data that comes out of the next year or two. The data is incredibly strong to show that carbohydrate dependency, so high muscle glycogen, coupled with carbohydrate intake and gels or sports drink or other approaches will enhance competition performance and there's a few mechanisms for that. One primarily is that carbohydrate oxidation is more efficient at producing energy or calories per litter of oxygen consumed. It's about five percent or five and a half percent more efficient and if we just even have a situation where you become one percent more efficient, that can be somewhere around 60 to 90 seconds in an elite marathon.

So, for an elite marathon or 60 to 90 seconds is a pretty nice jumping performance and while worth it. Conversely, we know that carbohydrates and carbohydrates in the mouth can also stimulate the pleasure and the words center of the brain and allow athletes to perhaps get a central or cognitive effect out of the carbohydrate as well. Indeed, there was about 15 papers of which 70--- around 60 or 70% have shown positive outcomes of carbohydrate mouthwash. So, I think from a fueling perspective in competition, the data is pretty strong that using carbohydrates as a preferred fuel for performance is the way to go. Where it gets confusing in the competition is people that are doing a marathon in 6 or

7 hours, or even 5 or 6 hours or people who are doing an ultra-marathon in 20 to 24 hours somewhere around there, where the VO2 demand drops for 40 or 50%.

So, in other words that those lower intensities, there is a large contribution of fat oxidation and at those lower intensities if you're a little bit less efficient with VO2, and so the VO2 demand goes from 45 to up to say 48 or 49% VO2 as a percent of max, who cares. You still have another 50% to go. But in your elite marathon or whose running at 85 to 90% of VO2 max, when his percent VO2 demand goes up because he's optimized and he is not feeling with carbs and it goes from 85 to 89%, that is the problem at at in because the intensities are already so high. And so, everything I have just said is for competition only and for elite athletes only.

And for me an elite athlete needs to be rank somewhere you know at least 4-5 hundred in the world in their event at the very least. They're making their national team to go to the world championships or whatever. So, this is--- these are quite elite. Now, conversely in training I have different philosophies but I don't know if you want me to jump into that now or not.

DANNY LENNON: Oh yes, for sure. I mean I think the---the carbohydrate periodization is something we can bring up and maybe we would need another full podcast to get into the weeds on that or not but just before we do, I think one of the important things that you hope, hopefully came across to people you're outlining there is like you say there is the issue that you can fuel some sort of exercise if it's particularly low intensity through predominantly fat metabolism. But that, there's often a misunderstanding I think of just how low that intensity actually is. And so, people think that high intensity is something like people sprinting or playing a field sports like soccer for example and then endurance sports, well they're doing it like for 2 to 3 hours so that's lower intensity and they can use fat for fuel which is obviously not the case if you actually look at what intensities and speed these guys are actually doing in the marathon, right?

TRENT STELLINGWERFF: So, I was lucky Abel Kirui visited Canada few years ago and we just did a classic step test on him. In fact, it was done by our colleagues at Canadian Sports Center Atlantic and they sent over his data because I work with Athletics Canada and I crunched his numbers. And long story short is there were claims coming out of Africa from Renata Canova a famed coach there who's Italian and he is a Physiologist that world class marathoners can now run a marathon at 4 millimole of lactate and it was always kind of thought that was probably what you can sustain for half marathon pace.

Well, lo and behold we took Kirui's data and Kirui is now just under 2:05. He's a two-time world champ in the marathon and we crunched all his data and lo and behold his pace at 4 millimole a lactate or onset blood lactate accumulation or threshold, lactate threshold was indeed about 255/km pace or 205 marathon pace. So, he is running for over 2 hours at a very high intensity and it ended up being about 88% of VO2 Max calculated from this task. And so, the world class athletes even over 2 hours have impressive, impressive caloric outputs which are very carbohydrate dependent. If you take a 6 hours sprint classic professional cycling race and nowadays you can get water data from Strava and from other locations and you just back calculate what's the basic calculations. Some of these guys are burning twelve hundred to fifteen hundred calories an hour for up to 6 hours in the—in those 6 hours sprint class, 6 which are full gas to a front stage is not run like that maybe the last hour does but it's impressive massive caloric outputs. So, you know we are not talking about the 4-hour marathon or here.

DANNY LENNON: Yes. I'm glad you added that context and I think just to get a clear in people's mind, we're saying that for purely for performance or for high end performance in any endurance sport really were looking at carbohydrates are still king and full glycogen stores with accompanying carbohydrates for performance are going to be beneficial. So, then the second thing that you've just brought up and I'll let you get it to the weeds on this trend is how we might--- may able to work with lower or low carbohydrate intake training phase for maybe some potential other reasons. And so, where is the

best place to start this whole conversation of thinking differently about whilst carbohydrates are best for performance, how do we even think about this idea of carbohydrate periodization, where's the best place to start?

TRENT STELLINGWERFF: Yes, I want to make two other quick comments on to finish off the fueling of competition discussion here is I do think there is an also extreme element where more carbs is always better and I've see a lot of athletes get into trouble in extremes sides as well. So, I think it's really important to just take time to work and individualize with the athletes that you're working with on both fluid intake and carbohydrate intake. Greg Cox and I, a couple of years ago did systematic review on carbohydrate. In that review, we actually have introduced a wider carbohydrate intake range than the consensus statements of about 40 to 110 grams an hour because I've worked with runners who have a lot of more ballistic up and down movements even running is quite jarring that can only handle 40 or 50 grams of carbs an hour and they're world class. One of them was 6th at the Berlin Marathon in Toten a few years ago versus I worked with cyclist on certain stages who can take 100 to 110 grams an hour.

So, the range is very wide and I'm not--- I think I'm never black and white, it's always gray and it's always content--- context specific. And the other comment I make about fueling is that there's been a lot of noise recently around Ketones. But the more data that comes out and the more I've heard of various professional groups playing around with Ketones. The more I'm convinced that for lead athletes, I'm not sure that the way to go. I've heard of taste issues, massive gastrointestinal issues. From a metabolism perspective, it's really needed an intervention. But from an application in elite sports, I'm not so convinced, so.

Anyways, that finishes off the fueling discussion there so hopefully that nails that. So, yes switching gears completely, I do think that there's a time and a place to strategically and proactively periodized macronutrients to try to get more out of training and specifically endurance training. If you were to ask me as a physiologist what is the number one

adaptation that you hope to get out of endurance training, I'm going to say Mitochondrial Biogenesis. How can we figure out ways to drive more mitochondria into your muscles? Now, a major misconception with that and what people would automatically jump to is I'm looking to increase fat oxidation. No, I'm not. I'm looking to increase the ability of broken down glycogen to pyruvate, to be oxidized aerobically in mitochondria through pyruvate dehydrogenase.

The increase in fat oxidation is secondary. Yes, it occurs at lower relative intensities, but I'm most interested in getting more mitochondria so pyruvate can be oxidized to a CO2 way and to produce 6 ATP rather than having pyruvate reduced to lactate and produce only 3 ATP. And that is a bit of a misconception I think with the word Mitochondria Biogenesis or aerobic training is, oh it's for the fat oxidation, no it's actually for aerobic oxidation of carbohydrates. So, when thinking about periodizing training or thinking about periodizing macro nutrients, for me that is the overriding rationale of why someone might want to periodically train with low carbohydrate availability and that might be low muscle glycogen in training bouts or that might be low blood glucose training bouts.

Blood glucose coming mainly from liver stores or existing blood glucose stores. And basically, in either of those situations you create a bigger stress from per minute of exercise and a bigger metabolic stress to try to induce a greater stimulus for Mitochondrial Biogenesis. And so, I look at it this way, it's very hard to mimic the demands and the feelings of the last 5 or 10 km in a marathon without having to run 30 to 35k in a workout.

When you're fully fueled and super glycogen, super compensated and you're taking in carbs all the way. In training that is a huge neuromuscular demand to try and do a workout like that to mimic the last 5 or 10k of a marathon. But through macronutrient manipulation, we can actually get an athlete feeling like that after only maybe 5 or 10 or 20 km of running just by strategically holding back carbohydrate in the diet and sometimes just over 4,5, or 6-

hour period. So, an example of that might be you have a marathon runner. Here she's going to do a really high-quality session in the morning on the track, let's just say mile repeats and so they have breakfast, they come in well fueled, they have lots of glycogen and they really do a great job on that workout and it is a really tough workout. So, during that workout, they--- because of running hard they decreases muscle glycogen somewhere on the order of 70-80% and then what we do is as one intervention we'll have them rehydrate, we'll have them eat but we'll have them avoid the macronutrient carbohydrate for the next 4 to 6 hours. If they get a little bit in there, it's not a huge drama but generally we'll give them a whole bunch of dietary options that are low in carbohydrate. And then in the afternoon, they have to come out and initially they might just try 30 to 40-minute run on low muscle glycogen and they feel pretty horrible actually.

Eventually, over 10,12,13,15 weeks, you can adapt some athletes where that afternoon session you might actually come out and do a 70 to 90-minute run with maybe half an hour of it or 20 minutes of it at goal marathon pace. And yes, you actually do feel quite rubbish, it is quite demanding but it does mimic the demands of the tail end of a marathon psychologically without having to run a marathon so from a neuromuscular perspective, that is an advantage in training because you can come a few days later and hit it again. But also, secondly, we also created a situation where metabolically in the muscle through a whole bunch of molecular signals I mean we could get really get into the weeds but we've created a situation where you've created an increase stimulus to make more mitochondria, more capillaries, more transporters associated with producing energy and that's it in a nutshell, it's like trained to manipulate. It's not a chronic low carb diet, you're just manipulating throughout the day or throughout micro cycles every 2 or 3 days where you might consume your carbohydrates more strategically.

DANNY LENNON: Awesome, yes, and there's plenty there. I was just going to ask about a couple of things and so maybe I'll just go through some of those just to make sure number one, I have

everything correct in my head so if I say that's incorrect please jump in and correct me and then just to get everyone listening we're on the same page. So, essentially what we're talking about is you have these strategic times throughout that kind of micro cycle where you're going to either use a low carbohydrate diet previous to a training session or in the hours leading up to it so that they do a certain type of training session with low glycogen availability, or there could be a case where after particular training session they go through their recovery window without refueling with carbohydrates. And we're talking about a--- the real reason here is to try and generate an adaptation from those training sessions and the big one you mentioned being the Mitochondrial Biogenesis and so, just two things just to confirm. Number one are we saying that in these particular training sessions that are done with low glycemic availability, obviously if we say that has the potential to impact performance but we're getting this beneficial adaptation, do we then now have certain training sessions over the week that are aimed at being ones we're looking for best performance and then these other ones where performance doesn't really matter if actually it goes down a bit because were getting this adaptation, is that correct way of viewing this?

TRENT STELLINGWERFF: Yes, so you hit it really well. There's a paper a few years ago that basically showed again in sub elite subjects that if you come in and you're doing an interval of a bike with low glycogen and this is a paper at a John Hall at his lab. You can expect almost an 8 to 10% decrease in power output when you're on the bike with low glycogen compare to a high muscle glycogen though you are correct in the quality of the training at least initially is lower in terms of the total power output. The fatigue is just as high if not greater and so I tend to look at strategizing these types of interventions exactly as you said that there's going to be some session during the week where you want a very high quality, a very high neuromuscular overload and so you know those sessions are going to be done with high muscle glycogen while fueled with breakfast just like you're coming into a race. Those sessions are going to be more prevalent in your

middle-distance athlete because the quality in training in athletes that have shorter duration in my humble opinion is paramount. Conversely, you can have other session in the week were you looking to create, even at a drop of power output or quality or intensity, you're looking to create a metabolic overload to try and induce further adaptations and that's the right action on the concept behind in periodizing these approaches.

DANNY LENNON: Perfect, yes. So, it's having this periodized nutrients intake based on priority of training sessions and the other thing just to come back to because I know you outline this really well but just to really confirm for people. When we're doing certain training sessions the slow glycemic availability or whether its carbo load strategy, we're getting certain adaptations that maybe then beneficial in the long term. So, Mitochondrial Biogenesis being important because we're going to have more mitochondria but the big distinction that you want to outline to people is that this increase availability for fat oxidation because of that, it almost irrelevant, right? And that it happens but it's almost a side effect that it's not really the target, so just purely seeing this romp up in fact oxidation is almost meaningless, it's just this kind of side effect that happens along with it, right?

TRENT STELLINGWERFF: Yes, and that's exactly what I'm getting at and another piece to that, it's very important to understand that a lot of training studies so if you do a published 10-week training studies. Most training studies obviously have a pre-test. Let's say the pre-test is 80% of the VO2 Max which is 250 watts, well after training the pre-test that most training studies do is not 80% of new VO2 Max, it's usually still 250 watts. So, after training 250 watts is way easier and so all these studies increases in fat oxidation because they're done at the same absolute pre-training workload.

But there are 1 or 2 papers in the literature at a George Brook's lab, the first author's Bergman where after the 10 weeks of training, they redid the VO2 Max and have them ride at the old VO2 Max and yes, there was easier and fat oxidation was up. But then they had them ride at the same 80% of the new VO2 Max and this instance it was no longer

250 watts, it was maybe 300 watts and guess what the percent fat oxidation is exactly the same as the pre-training when you ride in the higher wattage or speed and few utilization hasn't changed when you've re assess VO2 Max.

That was the key point, a really key point that sometimes missed on people and the vast majority of endurance athletes don't train at their old wattages, they continue to either run faster or to cycle harder as their fitness improves. So, they always ride at a relative internal load or RPE or percent of heart rate max, or percent of VO2 Max. Unless it's a very specific workout where you know thou shalt ride a 200 watts today. And so that's an important distinction to is that post training if you have people exercise or trained at their new relative intensity, then fat oxidation hasn't even gone up as a percentage. In terms of absolute calories of fat oxidized, yes, it's gone up but it still might be 80% carbs 20% fat just like before.

DANNY LENNON: That was really important to add and just what we're talking about some of this adaptations, I think remember James Morton printing on paper before that had showed some of the strategies leading to change in gene expression at within a muscle and just for someone who's not a Physiologist like yourself, are we seeing that this change in gene expressions are just things that are related to Mitochondrial Biogenesis and this adaptations were having or other adaptations that are happening at the cellular level that we are still working out might also have a benefit, so is there anything outside of increase of Mitochondrial Biogenesis that you think could be beneficial in mitochondrial adaptations from these strategies?

TRENT STELLINGWERFF: Yes, like if you look at the totality of all the studies that have done this, then outside of mitochondria it's often in markers of mitochondria. There's been indication that there's an increase in carbohydrate transporters, increases in fat transporters, increases in fat enzymes that are outside of mitochondria, increase markers in capillarization in terms of gene markers. From the muscle biopsy stated data, the outcomes are pretty robust and pretty impressive. I do want to absolutely highlight though that if you dig into the

literature and you look at the performance outcomes in these studies that have done periodized low carbohydrate availability training, the performance outcomes are not slam dunk in favor of this is the absolute best way to go. And part of that is because taking muscle biopsies and measuring gene expression or increases in various proteins is actually almost easier and they probably come as well before the phenotypic adaptations of an outcome enhanced performance. And most of these studies are 2 to 3 weeks in duration, was some of them only having over 3 weeks maybe 8,6, or 9 total workouts over 3 weeks that feature low carbohydrate availability.

So, there is more data required before we can say that this is an absolute slam dunk for a further enhancing performance. Above and beyond just chronic high carbohydrate training and so you mentioned Louise Burke and indeed she's done a series of papers on race walkers, the first ones out there and you'll see in there that the periodized carbohydrate group had the same performance enhancement 10k race walk as the high carbohydrate group. And so, it does beg question okay you know, this is a 3-week intervention, who knows what happens over multiple months but it's still a complex area of what is the best approach with our athletes.

DANNY LENNON: Yes, I'm glad you brought that up because that was the question I actually going to ask about when we're trying to look for research on actual performance outcomes versus some of the mechanistic stuff, particularly with the strategy of this is that a nutritional strategy, obviously there's so many inputs for these athletes unlike we've already talked about, a lot of them at least at competitive levels the potential for them to improve their performance incrementally is going to take a quite significant period of time to see a noticeable change or an up taken performance no matter what intervention I think. So, where do we kind of try pieces apart. Obviously if we have research that's going to show an actual performance benefitting great but in the case of something like this where that's going to be so hard to elucidate particularly like we're saying if were looking at the adaptation of increasing the amount of mitochondria, then to the point where that actually is going

to know sufficient amount of someone's time that could be a long way down the road. So, where do we draw the line between accepting the mechanistic data as our maybe our best estimate of hypothetically this is the best strategy use versus needing something that's looking at an actual performance outcomes.

TRENT STELLINGWERFF: Yes, my answer here would be the same as my answer even with emerging new supplements is that you're going to look at the totality of the data and first and foremost, do no harm. Have you somehow increase the injury or illness rate of the individual athlete because low carbohydrate availability training is more costly on the immune system. Or is there an intervention with the supplement or that actually go worse. There some gene study on caffeine now and with the gene shows a very small percentage of people might actually go worse. In the supplement perspective in terms of do no harm is this supplement clean, so with any interventions as usually where I'm at first and I should know that no study has yet shown that periodized carbohydrate availability training has been worsen their performance. Most of the studies a lot of them shows that it's the same and then now there are a few handful of examples that shows that it may enhance performance, so that's number one for me. Number two is I will step down and start to look at the data that's published. Do the molecular data makes sense, are the adaptation moving into the direction that one would expect with enhance performance.

I may reach out to experts around the world specially with the new supplement and say "hey" like question them. I'll look at contraindications, etc. etc. And then number three is once I got check marks on both of those, it's going to be trial in the individual athlete or on a group of athletes but trying to collect individual data on how they're responding, how they're feeling. Usually I try to be pragmatic as possible on that. It's assessing in training load, training quality, more in fatigue scores, ratings of perceived exertions during training, weight stability, performance matrix, maybe sex hormones or menstrual status and then finally injury and illness rate. And so, usually you're looking at a collection of

those types of parameters with an intervention say, yes this is moving in the right direction or this is working or no, we need to abandon this, it's too much.

So, you know for example if our Olympic rowers are in the middle of a really heavy training camp, they're rowing upwards of 300 km a week. That takes close to 30 hours of training and so, and some days are tripled days. Well if you look at the time course for glycogen resynthesis, if you're really aggressive, it's maybe 18 hours. Well they've got 3 workouts in under 10 hours. I don't need to periodized carbs because by workout number 3, there are going to be pretty low glycogen. And so, its's just again going back to that very first conversation we had, what are the demands of training, what are some estimates you can make from that. So. It depends on the context on what you're dealing with and how demanding the training is already. So, that usually how I approach any intervention.

DANNY LENNON: Awesome, and so just to kind of wrap this topic up, when it comes to all the current stuff that we have on low glycogen availability for training and the recovery phase, where would you like to see this area of research go to next or if there was a dream study that someone would go and fund that you are a part of, what is the going to be the next research question that you think would really advance our understanding, what would that study has to look like?

TRENT STELLINGWERFF: Yes, for me the two areas that are, or the couple of areas that I'd be most intrigue by one would be the ability to measure--- increase in our ability to measure glycogen in lead athletes. I know glycogen has been measured since the 1960 Bergstrom brought the biopsy needle in, but if you actually dig into the literature, there's a remarkable lack of data in quite of lead athletes, of what they use from muscle glycogen across their various types of training. And so, a better understanding of just that in a 30-hour training in a week with our rowers would be unbelievable to me but right now what require either invasive muscle biopsies or very good control with water content and using magnetic resonance or MRS, Magnetic Resonance Spectroscopy.

So that would be one area that I would be super intrigue by and you probably would have to do it with magnet and MRS. The other area that would then be a longer term intervention study where you were able to split out two training groups with pretty similar training where one is periodized carbohydrate where 3 or 4 sessions a week would be with low carbohydrate availability and maybe 2 sessions a week you recover over night with low carbohydrate availability versus another group where we clamp and try to have a high carbohydrate availability through the entire training. I know that's been done but most studies have only gone for maybe 2 to 3 weeks in duration and if there's again---money was not limiting I would extend that out very carefully measuring power outputs, adaptation, again it would be great to get muscle biopsies and performance outcomes. So, those are two areas that I think need a lot more work.

DANNY LENNON: Very cool. We'll start wrapping up Trent because we're just come up to time and I'd hope to ask you about some performance supplementations but maybe we can leave that for a future date if you're happy to come back on because I think it would be quite a lot or us to dive in to. So, before we get to final question where can people find out more about the work that you've done and the stuff that you're involve with? Is there any place online that you can send them or they go to check out more of your work?

TRENT STELLINGWERFF: Yes, sure If you're just interested in what we're have going on in Olympics training here in Canada, Canadian Sport Institute Pacific. If you just google search that, we have all sorts of unique content around various studies. We have ongoing--- we've just done an altitude iron study that we're working on. So, to general theme you can go there. I try to push out most of the stuff that we have going on in my twitter handle TStellingworth would be another good spot to check as well. Those are probably the two best spots to go to.

DANNY LENNON: Perfect. And for everyone listening, I will link up to those in the show notes so you can go and check that stuff out and with that that brings us to the final question we always do

on the show, Trent and this can be to do with something completely out of today's topic and if simply if you can advise people to do one thing each day that would have a beneficial impact on any area of their life, what would that one thing be?

TRENT STELLINGWERFF: I think hitting pause at the end of the day to count your wins and it maybe small wins like I got my boy to bed on time today. We get so busy and so crazy and there's so much stuff and politics coming at us that I don't know maybe it's Canadian thing. I don't think we spend enough time just even personally just saying that at the end of the day, hey what are 1 or 2 or 3 things that where wins for me today. I've started to do that more regularly, I try to do it every day but it's just--- for me resets how wonderful of situations that we are indeed in. There's always going to be some politics, there's always going to be some things that you can't control but just end in your day with positive note then it's been really helpful.

DANNY LENNON: Yes, that's amazing. I completely agree. I think we as humans are just exceptionally good at folks and all the things that have gone wrong, and all the things that were bad or that we need to get better at and not really think of the good stuff, so completely echo that and a great way to finish off at this episode, Trent I want to Thank you so much for taking the time to come out. I know you got super busy schedule, so for taking the time out to talk through the research, get that across to more and more people, I really thank you for that and yes, it's been great talking to you.

TRENT STELLINGWERFF: Great, yes. Thanks for having me here Danny. Have a good one.

DANNY LENNON: Same to you my friend.