DANNY LENNON: Mike, welcome to the podcast.

MIKE ZOURDOS: Thanks very much, I appreciate the time.

DANNY LENNON: No, it's great to have you on, someone who – your own work has been something I've looked up for quite a period of time and I've enjoyed anything that I came across that you have either presented on, talked about or obviously your own published research as well, and regular listeners to the podcast, would of course know how big I am about mass and the great work that yourself, Greg and Eric are doing. And so, I suppose, similar to appearances of the guys previously, we are going to take two research papers today and get into them and break this down for people listening. So before we do, maybe just for those listeners who haven't come across you or your work before Mike, what's the best way for them to introduce themselves to Mike Zourdos?

MIKE ZOURDOS: Sure. I am an associate professor at Florida Atlantic University. Florida Atlantic is down on the east coast of Florida obviously. And I am the director of our muscle physiology laboratory here. So, we do a lot of applied work and those that are familiar with the work are probably mostly familiar with the work on resistance training, program design, periodization, auto-regulation with RPE and repetitions in reserve and that sort of thing. We do that on a lot of

experienced lifters. But additionally, we also work with our – muscle physiology laboratory works with our biochemistry laboratory here, and we do a lot of acute and chronic look at inflation. Additionally, we are getting involved with a hospital close by to do work with resistance training and exercise oncology in COPD patients as well. So, we've tried to expand recently outside of just the practical application of it, but if you are familiar with us, it's mostly because of our work we've done on program designed for resistance training, looking at training frequency, training periodization, training volume and things like that. So if you've seen our work, it's probably that that's out there, but we are trying to expand a little bit and we have a nice lab here at Florida Atlantic, it's a big department.

DANNY LENNON: Yeah, for sure, and I think, again regular listeners will remember, only recently we had Ciaran Fairman on the show who heavily referenced work that you had been a part of and helped him with much of the work that they are doing, so, people will be familiar with that. To turn to today's episode, we are going to break down these papers. The first one, we are going to look at, and for everyone listening, I will reference both of these in the show notes, you can click through and pull up the full text of those if you wish. The first one is Fink et al 2017 titled effects of drop set resistance training on acute stress indicators and long term muscle hypertrophy and strength. So, Mike, I suppose, from the outset the best place to start is what was the actual goal of the study and what were we trying to answer with this particular paper?

MIKE ZOURDOS: So, the answer is straightforward, the main research question is, is using drop sets and solely drop sets a superior method to increase the skeletal muscle hypertrophy and strength adaptation over the course of a six-week training program. Now, the additional question was, what are the acute responses. So this study also compared the drop set to a traditional model, looking at the acute responses of stress. So blood lactate, looking at muscle thickness to essentially note, was there any swelling or was there more swelling in the drop set group after the training, than additionally to go ahead and look at was there change in strength immediately after.

So, the two main questions – what were the long term changes when just drop sets were used? Was hypertrophy and strength better than doing traditional three sets of 12 let's say, and then what were the short term or the short term or the acute changes? Was muscle fatigue greater in the drop set group? And what they did was they actually only used the triceps push-down exercise. Now, I know that's not how we normally train. That's one of the reasons that I wanted to talk about this study today is because it's a chance to also point out that research provides us with a concept, – it doesn't provide us with, hey, we take this finding from this study or we take this program and then we go and we do this exact thing.

So, this study broke down over the course of six weeks a triceps push-down group that only did drop set, meaning they loaded the weight to their 12 RM and then they did as many as they could to failure, probably about 12. Then, as soon as they were done, they dropped the load 20%, did as many as they could again; as soon as they were done with that, they dropped the load 20%, did as many as they could again. And they compared it to a group that just did three sets to failure with the 12 RM with 90 seconds rest. So a typical three sets of 12 versus a group that just did those three drop sets back to back.

DANNY LENNON: Awesome. And so of that methodology, before we get to any of the results, was there anything that you particularly liked too about this study in the way that they set up that was particularly noteworthy to mention from here?

MIKE ZOURDOS: So, there's nothing I guess out of the ordinary, noteworthy, but what I would like to mention is what I kind of alluded to a minute ago, which is that they only used this one exercise. And what I want to point out to the listeners here is that obviously, when we train, nobody is going to say, hey, for my training program, I am only doing triceps push-downs. But the point of that in a research study is that scientific studies especially in applied physiology are designed to answer a question; and the question is, if you isolate drop sets versus not using them, what happens to volume, what happens to time efficiency, what

happens to chronic and acute adaptations. Then you can extrapolate that concept to a whole-body training program.

So, one of the mistakes practitioners will make is they will look at the study and they will say, that's not how I would train, I would do more exercises so I wouldn't use it. And I agree that's not how you would train. But you would look at the concepts. So, the noteworthy part is that no, it's not a protocol that you would adopt, word for word if you will, and perform exactly as is, but it is a concept that you might adopt, and I want to get practitioners into the habit of thinking how to adopt concepts rather than literal findings and how to adopt concepts so they can integrate them with other concepts. So that's the noteworthy part here.

DANNY LENNON: Right. And I think even the flipside of that is, like you mentioned not to be dismissive of a particular paper, at least because it doesn't mimic exactly what they might see in practice, and even beyond that we could probably look at it in reverse of someone in their head saying, well, if I was there, I would design this exact study of this very too comparable training programs we might see, but the problem is trying to tease apart what actually the results would show, right?

MIKE ZOURDOS: Sometimes, designing a protocol that's almost too good doesn't allow you to answer the question. I don't know if this is something that you want me to elaborate on now or not, but there's a study that we did which I think the protocol was almost too good, and that's not a compliment of our study, that didn't allow us to answer one question. And so that's something, I will leave it up to you Danny if you want me to elaborate on that.

DANNY LENNON: Sure. Please go ahead.

MIKE ZOURDOS: Okay. So, there's a study that came up from our laboratory which was led by one of my former graduate students Alex Clemp who's off finishing his PhD at Florida State University now. And this study wanted to look at if essentially hypertrophy was different among different repetition ranges. So, we wanted to see, it's been said for a long time, and now we know from Brad Schoenfeld study from a few years

ago and from this study from our laboratory, that hypertrophy volume is equated at say, let's say 12 reps versus 5 reps. Hypertrophy is the same over the long term as long as volume is equated, that it's not necessarily repetition range dependent. But a few years ago, when this wasn't really known as well yet, our lab was one of the ones that wanted to answer this question.

So what they did was, we took an undulating programming strategy, and we took a frequency of three times per week, and we used this and what we call trained lifters that had about an average mass of let's say 150 kilos or so. Now, what we did was we had two groups, and the high rep undulating programming group on Monday did sets of 12, on Wednesday did sets of 10 and on Friday did sets of 8. So that's high rep, so they trained through the 8 through 12 rep range. The low rep did Mondays reps of 6, Wednesdays reps of 4, and Fridays reps of 2. Now, to equate for volume, the low rep group did more sets than the high rep group to equate for volume throughout that. Over the course of that program, over the course of eight weeks, hypertrophy was the same, meaning those that did only between 2 and 6 reps had the same hypertrophy to those that did 8 to 12.

However, they also had the same strength. And so, squat and bench press went up the exact same in both groups, meaning the lower rep group that had a far greater intensity, did not increase strength more than the group that did high reps. This is counterintuitive to almost everything else that we see. There is a relationship between volume and strength but it's not as strong as the relationship between volume and hypertrophy. The flaw was, the subjects were trained, but, they were most likely training one or two days a week with low volume on the squat and the bench press. We tripled their frequency and we added a lot of volume to it, meaning that even the high rep group, they were doing so much more than what they were doing before, it was a way better protocol. So their strength gains went through the roof.

So I don't think that allowed us to tease out better strength gains in the low rep group. I think if we

continued the study over the long term, the lower group would do better or if we had let's say an eight-week period where everybody did the same, like non-periodized training and then we started the study and then we diverted them, the lower group would have better strength. But I think our protocol was really, really good and something that I would program in the real world; but for a study, it actually didn't allow us to answer that question, it confounded the results I think where it masked them for strength, because the protocol was at triple frequency from what they were doing previously. So, both groups got stronger no matter what. So I think it answered the hypertrophy question but I don't think it answered the strength question. Thankfully, we have other studies that did that. So that's an example of not answering the question, but having almost a too good protocol. I hope that made sense.

DANNY LENNON: Yeah, 100%. I think that's a brilliant example. It illustrates things perfectly. To maybe turn back to the Fink paper, we are talking about, now we've got this triceps push-down, whether either doing drop sets or just conventional traditional three sets across. When it comes to some of the results, obviously there's a number of things we could look at, where's the best place to start in terms of results from this particular study?

MIKE ZOURDOS: Best place to start, I think for the listener, is the practical application in terms of the overarching hypertrophy and strength. And essentially, there was no difference. And why was there was no difference? Well, volume ended up being the same. So, there was no difference in the amount of volume that was done in the drop set versus the traditional group. So, the end result for hypertrophy and strength weren't any different. So, the one thing I would say though is that the drop set group, it took less time, it's a very time efficient strategy. So, you can accomplish in one drop set without any rest and doing as many reps as you can, dropping below 20% as many reps as you can and doing that three times. You can do that in about half the total time or less than it does to do the three sets with about a minute and half to two minutes rest between. So it's a time efficient strategy but ultimately

the results were not different between groups for the long term hypertrophy and strength changes.

DANNY LENNON: Perfect. Anything else that was noted that we can take from the results outside of those things that you think is worth discussing?

MIKE ZOURDOS: Yeah, one more point is that they didn't look at acute stress responses if you will. So that includes muscle thickness by ultrasound which will look at swelling, that includes heart rate, that includes blood lactate, that includes rating of perceived exertion or RPE, how hard the individual training session was. And all of those responses acutely or immediately following exercise were greater in the drop set group, meaning they felt that they worked harder, they did have a greater acute metabolic response if you will. So although, it's more time efficient, it is a little bit more stressful.

So, if that's – it remains to be seen if that's something that you could do all of the time, to be able to do that, so I think if you are getting the same results, you have a positive and a negative for drop sets here. One of the positives is that it's time efficient, but the negative is that it's acutely more stressful. So there's a little bit of a tradeoff there. So with practical results being the same, I think it tells you that, hey, you can have a little bit of a mix of strategies, you can have a little bit of flexibility in what you want to do, because you get the same results, but it is a little bit more difficult to perform, so that way you can perform that kind of when you feel like it almost or when you have a little bit more energy. But if you are not necessarily as keyed up for that training session, maybe that's something that you put on the backburner and you take the more traditional rest between sets.

DANNY LENNON: Sure. So, when it comes to applying this concept, obviously, drop sets are at least, pretty commonly across many people's programs that sometime they've probably tried at an intervention like this or other types of, let's say, something outside of strait sets. In terms of practical or aware people may apply this, is there a best setting or best phase over the course of what they are aiming for, how should we differentiate between the potential for something like this to in

strength versus for muscle growth if that makes sense?

MIKE ZOURDOS: Yeah, makes a lot of sense. So, I think this is really the key in any study is, and you can talk about the application of it, so, one of the other reasons that I wanted to pick this study out is because, I think people throw terms around like drop set, rest-pause set, cluster-set – when somebody would say, how do you train. Oh, I use drop sets. Well, that's not a theory of training. That's just one programming strategy, one minor programming strategy which within an overall program that meets the core tenets of either strength or hypertrophy training, that has strong periodization principles and all of these things, that come first, that's the more overarching picture. And then something like drop sets is just a programming strategy.

So, when can you use it? Well, let's first talk about, if let's say you are training for strength, when you would use it throughout the course of a macro cycle. Well, if you look at a macro cycle, volume goes down, intensity goes up over time. And during the first half of that, when volume is more prominent than intensity, that's your preparatory phase where volume is higher. So a drop set is a tool that is used to accumulate volume. So in a macro cycle, you would use it in a preparatory phase when volume is higher than intensity. Now, let's say the recommended training frequency is two to three times per week, so, you also wouldn't use it every day, and unlike the study – but again, the study was designed to answer a question – you wouldn't use it as a standalone method, you would do straight sets for the most part and you would do your normal training. Then you might throw it in at the end of one exercise. So when would you use this? Well, let's now say if training were training two to three times a week, let's answer the question on what exercises we would use it on, and then let's answer the question and when in the week we would place it.

Well, what exercises? Let's say you are doing lower body training and you have squat, you have leg press, you have leg extension, you have leg curl. You would probably use it on a single joint exercise. If you use it

on squat and you are training that lift Monday-Wednesday-Friday, and you do it on a Monday, and then you do three sets of 10 at 100 kilos, let's say that's about an 8 or a 9 RPE for you – meaning 1 or 2 reps in reserve, and then you drop to 20% of that, to 80 kilos, and then you do a drop set to failure, and then you have to squat again 48 hours later, you are probably not going to be squatting 48 hours later because it's going to create a lot of damage.

So the question is what exercises do we do then? Probably the single joint lifts. It's going to be – it's not going to cause as much systemic fatigue for the long term if you use it on a leg extension or a leg curl. You also aren't running the risk of injury by doing something to failure after you are already on the single joint lifts that don't have as much complexity. Then if we look at where are we going to place it throughout the week, if you are training Monday-Wednesday-Friday, you place it on a Friday, the reason being you have 72 hours before your next training session, whereas if you do that on a Monday or Wednesday, you only have 48.

So I think you position it so it doesn't affect your next session which is a bigger concept that's not necessarily for today, but that looks at how do you allocate training volume throughout the week. We hear so much about volume and drop sets are a component of that, but you don't want to misapply them. If you put them on a Monday and you do them on your multi-joint lift, and then you want to come back and train again on a Wednesday, you might have done more volume in one day with the drop set, but you are probably going to get less volume throughout the week because you are not managing fatigue well.

So, practically, I would put them at the end of the week if you are using a two to three time a week training frequency, where you have the longest to recover, because it's a set to failure that's damaging, and then it would also probably keep them for the most part to the single joint or at least the non main lift in your program, because those should cause less fatigue than the main lifts. And then for hypertrophy, it's really hypertrophy, I don't necessarily look at macro cycles as much as I look at meso cycles and it's

the same concept, just not letting it affect the rest of that training session, I guess, or the rest of that training week through fatigue.

And the last point, I would say is that even though you typically want to train with only drop sets, the study does provide good evidence that if you are in a time crunch one day, you get called in to work, you don't have much sleep the night before, you are tired, whatever it is and you are in a time crunch, and you need to get all your volume in, in 30 minutes, drop sets are a good way to do it. Because you know in the long term, this study shows you can get the same results even though you don't want to do it all the time and you only have 20 to 30 minutes that day, then you can drop set everything and get all your volume in on that day if you are on a time crunch. So single joint exercises, end of the week, and time crunch.

DANNY LENNON: Perfect. Just while we are on that topic and something maybe related outside of this particular paper that I wanted to ask about, just while we talk about using strategies like drop sets as part of someone's training, obviously we've mentioned so far that if you match volume and you are looking at hypertrophy for example, it's kind of we'd expect to see pretty similar results from something if you have volume equated. And so, in practicality, if we were to see a benefit for using whatever type of method it is, it maybe that a particular type of method for this individual allows them to drive more training volume.

Now, outside of that, there's also people that maybe proponents of certain ideas for reasons other than volume. So if you look at, for example, driving muscle growth, I think most people are kind of aware of how mechanical tension plays in that, we are starting to see more about hypotheses around the metabolic stress part of that and muscle damage. And you will have people on one side saying, these are very important drivers in and of themselves with muscle growth. On the other, people making the point that really they are just byproducts of the mechanical tension in the first place. So, based on that, I am just wondering, what particular way do you think the evidence leans towards, what's the best way to think about those ideas of driving overall hypertrophy

through not only any mechanical tension but things like muscle damage, metabolic stress and what actual influence they have?

MIKE ZOURDOS: It's a great question, and it's amazing that it's 2017 and it's amazing how little we still know about this and how nobody can really say with absolute certainty how important metabolite buildup is, how important all of these factors are. So, my response to this is that I am on the side of them being byproducts of mechanical tension, and that muscle damage certainly isn't the goal. Metabolite buildup isn't necessarily the goal although I think it's more of a goal than muscle damage. There is a study looking at rest-pause that came out recently, that did show a little bit more benefit for rest-pause training, which would be doing a set of – having a predetermined number of repetitions, let's say 30, you know, putting a load on the bar and the bench press 100 kilos, doing as many as you can, resting 20 seconds, doing as many as you can, resting 20 seconds till you get to that. That would be rest-pause training. And there is some evidence for that to be efficacious, but I think muscle damage is the key one here that you pointed out in that.

So, here's how I explain this when I am lecturing at the university to my students. I always give them this explanation, because they are at the university rec center and they see everybody going to failure all of the time, creating all of this damage, that's right now, Monday bench press day, that sort of thing.

So, I always explain to them, hey, you go in a gym on Monday, in the rec center here and you see somebody and they are just, they are killing it, they are going crazy, and they are doing 10 sets of 10, on everything and they go, bench press 10 sets of 10, squats 10 sets of 10; and then you have somebody else and they go in, and they do similar amount of sets, let's say, let's back off that set, let's say the first person did 4 sets at 70% and they went to failure on everything. Maybe on the first set they get 15 reps, the second they get 11, the third they get 7 and then fourth set they get 5.

Somebody else goes in and they do 4 sets of 8 at 70%, maybe they have about a 5 to 7 RPE on each one. I say, well, if you do those all 4 sets to failure, and I tell

you, I want you to squat again on Wednesday, are you going to be squatting on Wednesday? And they shake their head. They look at me like, no way, that's crazy. And yeah, no, you are not even getting out of bed on Wednesday. But the guy that did 4 by 8 and stayed at a 5 to 7 RPE, you want him to squat on Wednesday, he's coming back to the gym, he's doing that. I say, on Friday, he can come back to the gym again if he does another session that has 4 to 5 reps in reserve. The other person might come back to the gym on Friday. So I would say that's a frequency of 1.5 times per week for the person that went to failure and that's a frequency of 3 times per week for the person that didn't go to failure. Although, person A may have gotten more volume in one day, person B got more volume throughout the course of the week. And we know that volume of the training variables is most closely associated with muscle growth.

Now, nobody should take that concept to the extreme. We also know that too much volume is a bad thing, and that's certainly another concept. But volume within reason, within what the individual can handle is going to promote muscle growth. So, I think it's good evidence, when you break it down like that, that you can accumulate more volume if you are staying shy of failure and you are staying shy of the amount of muscle damage that that can produce.

There's a really good study from Flann & colleagues in 2011, this was important for a lot of the research that I was designing. And I maybe fuzzy on just a few of the details, but the basic tenets of the study were that there were two groups and each trained for I believe 11 weeks. Now, one group trained the entire 11 weeks and the 3 three weeks were kind of like an introductory cycle and they built up and they did such light training that when they did the heavier training in the final 8 weeks, to finish out the 11 weeks, there was no detectable muscle damage. The other group, they didn't do anything the first three weeks. They skipped the intro cycle.

So, to equate for volume, compared to the other group, they had to do more work in that last 8 weeks, they had a lot of detectable muscle damage. The differences were the increases in strength and

hypertrophy were identical between groups, meaning, this tells me a few things – one detectable muscle damage isn't necessarily a prerequisite for growth and for strength; and two, if you are going to train, utilize an introductory cycle, don't jump right into that first week of training. And we've all written down a training program where we write things down and we think, hey, well, I am going to add 5 kilos this week, 10 kilos this week and next week I am going to be so strong, I am going to be as strong as Bryce Lewis. And that's not the case. You are not Bryce Lewis, you are not Mike Tuscherer, that's not the case.

So, utilize an introductory cycle, you can stay away from muscle damage and see the same result. So I think the data is there, at least in a practical sense to show us that that's not the goal, rather the training volume is the goal. Then the question for me becomes, how much, what your dosage of training volume is, and your dosage is really individualized, I would say it's what allows you to continue to train multiple times a week on a muscle group and I would say you can accomplish that dosage by same sort of failure – by same sort of failure in one session you are going to be able to recover more quickly and perform more training sessions, thus more volume over time. So my response to you and to your initial question to circle back is that muscle damage isn't the goal, if anything, I think you want to – it's a byproduct, it's going to happen but you want to minimize it through allocating those training variables appropriately.

DANNY LENNON: Perfect. Mike before I move onto the second paper, is there anything either on this first paper by Fink or any of the concepts related to that drop set paper that we didn't get a chance to touch on that you want to mention before I move on?

MIKE ZOURDOS: No, not necessarily, I think that paper is pretty straightforward, just again, encouraging everybody to use it and allocate it appropriately. Take the concept from the study, not necessarily the exact protocol and implement that. If you understand the concept and review what we talked about, that will allow you to put that into your program in your own style. It might not be exactly how I described it earlier or we discussed, but as long as it fits with those principles, it's still

correct. So, we are all in training program design and that's like we are all kind of guessing a little bit, it's data that we have to extrapolate and then use our experiences. So take the concept from that, play around with it, see how you can put it into your weekly meso cycle or your weekly micro cycle to meet the principles we talked about and you will be just fine.

DANNY LENNON: Perfect. So with that let's turn to the second paper. So again, for people, I will link to this in the show notes. This was a paper out of Chtara I believe Murlasits, et al, if I am pronouncing that correctly, et al, 2017, titled the physiological effects of concurrent strength and endurance training sequence, a systematic review and meta-analysis. So Mike, where is the best place to start here? What's the first kind of few things to mention on this particular paper?

MIKE ZOURDOS: So this was a meta-analysis and I am sure that most of your listeners are pretty familiar with meta-analyses and that they are essentially looking at all of the studies, they have inclusion criteria and are analyzing all the studies in one area. So what this set out to do was to look at the – if there's any differential effects and how you can figure concurrent training – concurrent training being the simultaneous inclusion in a training program of both aerobic and resistance exercise – and this wanted to look at the order, meaning whether different strength and endurance adaptations when resistance training came before aerobic training or where the different adaptations of aerobic training came before resistance training, meaning when they were done on the same day. This meta-analysis wasn't looking at when concurrent training was done on every other day, let's say, lifting weights on Monday, cycling on Tuesday, lifting weights Wednesday, running Thursday, it wasn't looking at that. That's another concept that we can definitely get to, but this was just looking at the same day. The order of aerobic and resistance exercise matter for maximal strength gains on the lower body and VO2 max.

DANNY LENNON: So, just with that before maybe get to some of the results, when they are trying to do a meta-analysis of this and they are looking at lower body strength, what

they decide that they would include and that they wouldn't include as a fair measure of that, because obviously we are forgetting different particular metrics of assessing lower body strength in different studies, how do they kind of consolidate that?

MIKE ZOURDOS: Yeah, so they had – in this study, they had papers that looked at squat, the leg press and the knee extension and the leg extension. So, they needed to have actual true 1 RM measures and there actually weren't a lot of studies that had – there were only nine studies that looked at this and these lower body exercises that were included. And they had to be, again, they had to be on the same day either before or right after aerobic exercise. So that was their inclusion criteria, it was pretty minimal amount and they were only six studies that looked at VO2 max and looked at that endurance training.

So, when we do present these results in a moment, if we keep in mind that it's only nine studies looking at strength, that's a pretty small amount. So, even though if we have our pyramid, not to steal a term from Eric, but if we have our pyramid, at the top of that pyramid is meta-analysis usually, I mean, that's what we hold up in the highest evidence and scientific evidence. And while I don't disagree with that, I do think that that's valid, we always have to keep in mind that sometimes in a meta-analysis, there are only a few amount of studies and a meta-analysis can also have limitations, mainly, a meta-analysis can only examine what's been done. For example, we know from meta-analysis that for hypertrophy, 10 plus sets per week are recommended. However, we can't conclude yet if 15 sets are better than 10, if there's a dose response above that for hypertrophy.

The reason I bring that up here is that meta-analysis can only examine what's been done in the literature and on the spectrum of trained lifters, I think the dosage of volume needed to progress hypertrophy is higher the more trained you are. However, if we think of lifters on a scale of 1 to 10, 1 being poorly trained or beginners and 10 being highly trained, most of the lifters used in the literature are probably a 3 or a 4. So, I do think 15 sets is better than 10 for people that fall on 7 or an 8 on that scale; we just don't know that yet.

So, I know again, I am not trying to go too far off the rails, but I hope that helps to point out how there are limitations in meta-analysis even though that's at the top of our pyramid. And in this meta-analysis, I think one of the limitations is the very small sample size that only had those 9 studies, but, again, it's not the meta-analysis' fault, it's that that's all there was out there.

DANNY LENNON: Yeah, for sure. I am glad you bring that up because it's particularly interesting how often you see people have like hold up meta-analyses as this all encompassing super thing that can't be wrong, not understanding that, like, a poor meta-analysis is almost more "dangerous" than a poor study, like it's harder for people to wrap their head around and anyone or two errors can compound pretty quickly in that. So I think it's really interesting to bring that up. With this particular study then, what is the first few things we should start to mention about when we look at what it was reporting?

MIKE ZOURDOS: So, the main thing and you reminded me of something Danny, which I will get back to in a minute on other limitations of meta-analyses. But the first thing that I would point out here is that the findings for 1 RM strength, the max strength were pretty clear. And that 1 RM strength is better. If you have to perform concurrent training on the same day, aerobic and resistant training on the same day, which is not advisable, you would rather do them on opposite days. But if you have to perform them on the same day, performing resistance training before aerobic training is better than performing aerobic training before resistance training; and I think that's only logical.

So, if you think about this, again, I always ask my students when I talk about concurrent training, they say, well, if you have to do them on the same day, which one should you do first. I say, well, which one do you care more about, which one do you care more about your performance in. If you care more about your resistance training performance, then you are going to want to do it first. If you do the aerobic exercise first, that means you are going to be fatigued, you might deplete glycogen stores from that aerobic exercise, you are going to have energy, that's

expended, and it's going to be more difficult to perform your resistance exercise. And there's a good paper in 2003 that shows that the amount of volume you can perform when lifting weights, when it falls about four hours, within four hours following aerobic exercise is diminished by about 75%.

So think of it this way. If you can do 4 sets of 8 with a 100 kilos on the bench press, but you go in before that and you run or cycle for 30 minutes, and then you do that 4 sets of 8 and it's decreased by 75%, now that means you are doing 4 by 8 at 75 kilos, that's a reduction in volume. If you were to do that for all eight weeks of your training program, that means you have less volume, you also have less intensity, meaning you are going to have a lower hypertrophy and lower strength adaptations. So, this simply shows that when you do strength first or resistance training before aerobic training, your pressure, you can handle high intensity, handle higher volume, you are going to get better adaptations than if you do aerobic training first. That's the main take home from this, which I think is pretty logical, but then there's a lot of mechanism and nuance and we just discussed some of it that we could certainly go into.

DANNY LENNON: Yeah, one thing that may or may not be relevant that just popped up as you were talking there is, is there some type of time course that we need to think about especially in the real world of let's say someone does have a suboptimal training program set up where they have this sequence incorrect and they are doing at least against what we would class as a good way to program – is there a certain period of time where they are likely to be able to get away with – I mean, the decrease in performance while we might detect it in a study, might not be obvious to that person from the get-go, do you think it's more an issue of they do it over a period of time and it's only later down the road that they will maybe see some of those negatives?

MIKE ZOURDOS: Yeah, first and foremost, I think this is really the best question that we can possibly ask, which is, okay, but what's practical. Meaning inevitably, life gets in the way and we are going to have to do these things on the same day, we can't do everything that is exactly perfect in the scientific literature in our own training

all the time. So I agree with you. I think that if you have to lift weights right after aerobic exercise, one or two times, it doesn't matter, it's one or two times. It's going to take a while for that interference and that's what we call the interference effect which is the attenuation of hypertrophy, strength and power because you are including aerobic exercise. It's going to take a while for that interference to manifest. It's not like you do one session and all of a sudden, lower volume in one session, it's all over, everything is terrible, that's certainly not the case.

So I think it's going to take time, but then how can we practically do that? Again, like we said, ideally, there's – in everything I like to say that there's tenets, and like for resistance training, tenets two to three times a week, 10 plus sets per week. For concurrent training, there's tenets, ideally, the tenets are that you keep aerobic training and resistance training on opposite days. The tenets are that cycling is better than running because cycling doesn't cause as much muscle damage. So the interference isn't going to be as great. The tenets are that you keep the aerobic to maybe 30 minutes or less, that's not going to cause as much interference. The interference is time dependent.

So if you can keep those tenets, you are going to be pretty good. However, if you can't, then you have to do them on the same day, you would choose resistance training before the aerobic exercise. If you can't do that, then you have to do the aerobic training first depending on your schedule or whatever it is. I would try to keep it more than four hours before the resistance exercise. If you can't do that, try to then keep the aerobic exercise, if it's right before the resistance, so that the resistance exercise you do that day is upper body and the upper body won't be nearly as affected as the lower body would be.

So essentially, we try to maintain all of our tenets; if we can't, then we essentially try to get the lesser of all of the evils in those situations, to break it down to avoid the interference effect as much as possible. I also think the interference effect is something that is overblown a little bit. I think there's no question, and this reminded me of something you mentioned earlier. There's no question that aerobic exercise

interferes with hypertrophy, strength and power; but when we look at studies, we have to realize that they design them to elicit this effect, because studies oftentimes want to look at mechanisms, they want to say, okay, does increasing AMPK down regulate mTOR, does that decreased protein synthesis decrease the anabolic response.

Well, we know it does, but if you want to elicit that effect, they crush the participants with tons of aerobic exercise, so the quintessential study showing the interference effect from Hixson in 1980, that study has the individuals that are – there's three groups, a group that just does resistance training for 10 weeks, a group that just does endurance training for 10 weeks; and the group that just does resistance training lifts weights 5 days per week; the group that does endurance does it 6 days per week; and then the third group, the concurrent simply does both of those protocols. They do resistance training 5 days per week and they run 6 days a week. Well, of course, you are going to see the interference effect when you do that, it's designed to do that.

But, you can get aerobic adaptations from cycling at 40 to 50% VO2 max two to three times a week for 30 minutes. If you do that on opposite days when you lift, I can tell you, the interference effect is going to be pretty much non-existent. So, again, that's what a meta-analysis does too, it's only looking at studies that are designed to elicit a response. So I think it's important to keep that in mind as well. We got a little bit off topic from your question there, but I do hope that that information was helpful.

DANNY LENNON: Oh, for sure. I think that's so critical, and I think – because this comes up all the time. I mean, even outside of this topic of, I suppose a classic example when people are now looking at the effect of load has on the ability for someone to build muscle and why we are seeing studies comparing 30% of 1 RM and 80% of 1 RM, people are like, well, why don't they just do like 50 versus 60. Like, well, that's not really going to show much. And it's the same in nutrition like you are not going to see a study comparing a calorie deficit of 5% versus 7%, because it's almost going to be impossible to detect. I think that's a super important

point. And the other thing that popped up is I was going to ask you about modality but you kind of already mentioned that something like cycling is better than running. So with the selection of endurance modalities, is it basically anything that will just reduce muscle damage or is there anything else to consider for people?

MIKE ZOURDOS: Yeah, it's a great question and just to take it back to the examples that I give to my students here again, we often talk about cycling and running in class. I will first present why cycling is better and then I will answer your question by posing the question that I posed to them. So, our cycling is the superior choice than running if they are looking to minimize the interference effect, maximize their strength and hypertrophy adaptations. The reason being really twofold; one, running has a strong eccentric component when you are pounding on the ground, and that causes a lot of muscle damage. So, when you cause damage typically, even though damage isn't the goal of resistance training as we said earlier, it's a byproduct. That damage ultimately will repair itself. But remember, the acute protein turnover ratio following endurance exercise is much more negative following endurance exercise than is resistance. It's still negative following resistance; but following resistance, protein turnover ratio gets to a negative rate but protein synthesis still increases. Following endurance exercise, protein synthesis doesn't increase and there's a huge change in protein breakdown, so it's more difficult to repair that damage. Glycogen stores are decreased as AMPK is increased; mTOR activation is decreased as well.

So, these are the mechanisms that show the damage that occurs with running is going to be more detrimental. With cycling, there isn't really an eccentric component. So, the damage just isn't there with cycling, so the recovery time isn't as long and from a practical perspective, if you are going to run and you have damage let's say on a Monday and then you went into your lower body on Tuesday, you are still going to be negatively affected. The other thing is if you've seen somebody jog for a long time, the HIIT mobility that's utilized in jogging isn't really very good, but in cycling it's a little bit better. So if you are

doing things like squats, snatches, clean and jerks, you are going to have much better mechanics if you are still cycling as opposed to running which may harm those mechanics. So the damage associated with running and then the poor mechanics that are associated with running that don't transfer to lifting will harm them.

And then if you think about, now to the second part, which is what I pose for my students when they say – they then will say, well, how about rowing or how about swimming or how about something like that as a mode of aerobic exercise. And I would say just apply the concept again getting back to that word, apply conceptually. Are they going to cause as much damage as running? No. So if they don't cause as much damage, there should probably be better options. If we are going to look at using a rower, that might actually stress the upper body more. So if you go back to our tenets before, and we say that upper body resistance training, is it negatively affected by doing lower body endurance training right beforehand – well, if you do a rowing exercise, if you are on a rower for an hour, and then lift weights, that's probably going to affect your upper body more than your lower body.

So apply that concept the same way. I think cycling is your best bet, but if you do something like a rower, I don't think it will cause damage that running will, but I think in that case, that's going to affect your upper body in terms of acutely – and so then you would want to keep your upper body training 24 hours removed from when you were on the rower. So if you understand things conceptually, you understand how these different modalities of rowing exercise are performed and you can understand how to apply them.

DANNY LENNON: Yeah, sure. I wanted to talk about one more thing on the kind of practical application, it was a point that you brought up around obviously when we are looking at a study and certain intervention they may use to try and induce some of these things is going to be vastly different from, for example, going for a half-hour job, a couple of times a week, like you mentioned. The other thing you mentioned is obviously who we are

talking about here and then therefore how important this stuff maybe, and I think for maybe people listening who are practitioners, rather than the take home being you must program this, in this specific way or never have these issues, it's obviously going to be a different consideration if we are talking about are you preparing an elite level powerlifter for a meet or do you have like – someone from the general population just wants to be healthier, because even if there are maybe strength training performance dips for the next few weeks because this is the only time they can train, does that matter, whereas obviously with the powerlifting example, it clearly does matter if strength is affected. Right?

MIKE ZOURDOS: Yeah, I agree a 100%. So, just to kind of make it analogous to something else and since you guys talk so much nutrition here is, we kind of know now that protein timing immediately following resistance training isn't that important, but it might make a small difference. So if you are an elite athlete, would I go out of my way to recommend an elite athlete have protein immediately following resistance training? I probably would if it makes a 1, 2, 3% difference. But for most of us, in the gym, does it matter if I have protein immediately following training? It doesn't matter. I am not that, that big of a deal – I am not that good at this.

So, I do think there's a difference. If there's a powerlifter who's at the highest level and I am coaching him, we are going to break down all of these variables and we are going to meet all of those tenets to make sure that we have aerobic training on opposite days, we don't cause the interference effect, we use cycling instead of running and that sort of thing. But, for the practitioner, I think it's good that the practitioner has these guidelines. However, they also have to present it in a way to their clients or program it in a way, of course, that they enjoy and they can adhere to, and they try to minimize the negative effects, but there's simply no way around all of them all of the time, it's inevitable.

So what I would say to them is try to avoid it as much as you can, but make sure that your client's enjoying it as well. And so, just to throw something else into this,

over the last however many years, HIIT has gotten so much praise in terms of, hey, if we are a bodybuilder or a powerlifter, we are going to utilize HIIT instead of steady state aerobic exercise, because steady state aerobic exercise causes the interference effect. And we've seen that in these meta-analyses, but we just talked about how these meta-analyses or the studies are designed, like Hixson study was 6 running days a week, to show that effect. So that's what the meta-analysis picks up on.

So, I am actually – when we look at this though, and then I will tell people, hey, I think there's an application for steady state exercise over HIIT. And they will say, why, the data doesn't show that. I will say, mechanistically, no; but practically, yes – meaning, what takes more mental fortitude to do, go sprint for 30 minutes or ride a cycle at 40% VO2 max for 30 minutes. Sprinting for 30 minutes, that's cycling at 30 minutes at a low intensity doesn't really cause the interference effect. Also, the sprinting will cause you to be fatigued for the next few days and might actually hamper your lower body training indirectly, not mechanistically, but because of the damage response over the next few days, whereas a steady state cardio won't.

So, I think, what I will try to do with people is use a flexible template with that and say, hey, I want you to get 6 cardio sessions in over the next 2 weeks, that's 3 a week. I want at least 3 of them to be HIIT, but 3 of them could be steady state. Use these principles. On the days where you have more mental fortitude do the HIIT, position the HIIT, so it's let's say, 48 hours away from a lower body session; if you have to do the steady state cardio after a lower body session or the day before, go for it, it's only 30 minutes. That way, they will adhere to it better. So I think that's a really practical guideline as well as sure mechanistically that's not showing the best mechanistic benefits, but if we abide by those tenets, the interference effect is going to be non-existent. Also, if you tell somebody, hey, you got to work at 90% max heart rate reserve every cardio session, they are simply going to miss sessions. So I don't see the practicality of that, and I see the fatigue lingering for something like that for a little bit of time. So again, I know sometimes we are

going off and not necessarily tangents but going a little bit more in-depth than the initial question, but I think that's important, so again, I hope that concept makes sense too.

DANNY LENNON: Absolutely. And I am very keen to hear more of these thoughts, but we are going to start wrapping up fairly soon. Before I get to the last kind of final question, Mike, maybe one last thing on this particular topic of the interference effect and it's, when we think about questions that are still to be answered on this, I am sure there's plenty of mechanistic stuff that we could still work out of what might be going on, but from some of the kind of big picture stuff, like you mentioned earlier, there are these core tenets that we can use for programming, what else is there in research that you still think is unanswered on this topic that you think we would be nice to see emerge over the next 5-10 years on this topic or the next kind of few steps along the road within research?

MIKE ZOURDOS: On concurrent training specifically?

DANNY LENNON: Yes.

MIKE ZOURDOS: I would like to see a study that actually abides by all those tenets over the long term, in that, we have a lot of studies designed to elicit an effect, but we don't necessarily have a lot that abides by those tenets over let's say a 20-week period, to actually see if not only the acute but if let's say the neuromuscular long term, the divergent fiber type adaptations or fiber type inter-conversions with aerobic exercise versus resistance exercise if we keep that cycling to 30 minutes on opposite days – does it have changes in the neuromuscular effects? Is that enough of a stimulus of aerobic training to cause inter-conversions away from 2x and 2a fibers toward type 1? Does that have enough of a stimulus to reduce rate of forced development, to reduce rate coding – that sort of thing.

That's not something that I am sure we know yet in terms of over that long term, but it's something that I would like to see. Something that we did here, in our laboratory, which isn't published yet, although the full thesis is available – it's one of my students, my

student Chad Dolan, who some of you guys maybe familiar with – his thesis was on concurrent training. And what we tried to do, what I thought was important in this area at the time was, we had 4 groups that trained over 8 weeks, each group lifted weights, Monday-Wednesday-Friday, and then did cardio Tuesday-Thursday. One group did sprint cycling for 30 minutes, other group did 40-50% VO2 max steady state cycling for 30 minutes. And then one group did nothing control, and then the other group did circuit resistance training for 30 minutes.

And we wanted to see if that would actually expend the same amount of calories and enhance resistance training performance because it was added volume. What we found was pretty interesting. It didn't enhance resistance training performance and may have even hurt it because we were doing more volume but it was at such low intensity and so damaging, that it didn't necessarily allow for recovery. Additionally, the 30 minutes of modern intensity cycling caused no interference effect whatsoever, even though it was done within 24 hours of the resistance training.

So I think that's a very practical guideline and that's something that sounded good in theory, and we hypothesized that the circuit training group would have the better strength result, because of the added volume, but we were wrong. That's how science goes. Our hypothesis was flat out wrong. So, I think that's pretty cool. That's how you learn. So we still have yet to publish this paper but we are working on it. But anyways, I think that's something that hopefully we can get into the literature soon, that will help answer some of these questions that from a mechanistic perspective looks like it's pretty clear what the results would be. But then, when it's implemented, practicality didn't match up in that case and after the subjects were going through the study and we watched them, and I said, what I thought mechanistically maybe right, but practically, it just doesn't play out that way and it's not feasible. So, even as a researcher, it was pretty cool to watch that play out and be wrong.

DANNY LENNON: Yeah, for sure. That's awesome. Mike, you've been very kind with your time, some great information

today. Before I let you go, for anyone who's interested in finding out more work that you've either published, anything you are involved with, where is the best place for them to go on the internet that you'd like to send them?

MIKE ZOURDOS: Sure. I don't have a lot of internet destinations, but the two things that you can look for, where we put work out in a practical manner, it's one, Danny you are certainly familiar with MASS, Monthly Applications in Strength Sport, myself, Eric Helms, Greg Nuckols, Lindsay Nuckols, just phenomenal team, so you can. If you go to Greg's strongerbyscience website or search MASS, you could get a hold of that. Shredded by Science, that I work on with Luke Johnson, Laurence Judd and Eric Helms is part of that as well, just phenomenal group, those guys are brothers to me, you can look for them. You can certainly look up our laboratory on PubMed and find our new research. I have a personal Facebook page and then on ResearchGate we try to get a lot of our full text on there, and we have right now, either about 10 papers in press or in review and others that are being submitted and that's just a testament. I have phenomenal graduate students and colleagues, so we should be coming out with more stuff soon.

DANNY LENNON: Awesome. And for everyone listening, I will link up of course all of that stuff in the show notes, please do go and check that out. I will also link to the two papers we discussed more in-depth in today's episode that you can go and find at that show notes page. So with that Mike, I want to say thank you so much for coming on, it's been great to talk through this stuff. Like I said at the outset, I really love any of the work that you are putting out and obviously well-deserved that your lab is well-regarded as probably the place where most of the best quality strength training stuff is coming out that people look for. So, kudos on that and thank you for coming and sharing your knowledge.

MIKE ZOURDOS: Thanks man, those are kind words, I appreciate it.

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