DANNY LENNON: Dr. Robin Tucker, thank you so much for joining me on the podcast today.

ROBIN TUCKER: Happy to be here, thanks.

DANNY LENNON: Yeah, I think, as I've mentioned to you over email, I've really found a lot of your work incredibly interesting and informative to read and I definitely have lots of questions, and I want to dig into some of the specifics around that. But just to get us started, what is the typical way you would introduce the type of work you're doing, where you're based, anything that might be relevant for today's conversation just to get people up to speed?

ROBIN TUCKER: Yeah, so I think my training is, as a dietitian, and when I was going to school, we always talked about what happened after people ate, the digestion, metabolism, the effects of eating but we never really talked about why people were making those decisions in the first place. And so I became really interested in these questions about food choice, why people choose the foods that they do and the factors that influenced those food choices, and then obviously the health outcomes of those food choices since what you eat has such an important role in terms of your health outcomes, your bodyweight, your performance

goals, and so on. So I think the overall goal in a broad sense is I'm interested in understanding food choice so that we can hopefully help people make better food choices and reap the benefits of those choices in terms of overall health. And there are a lot of factors that do influence food choice, I'll tell you at least in the developed world, sensory factors are probably the most important, and what I mean by sensory factors are the things that contribute to flavor, so taste of food, the smell of food, the texture of food. And when you ask people why do they, you know, what's the important factor driving their food choice, they say taste or flavor. So I think it's important to understand how taste and flavor are experienced and how that can influence food choice. And so, a lot of my work has been looking at how differences in taste acuity or taste sensitivity and taste perception influence food intake. And when I was doing some reading, I noticed that several reports had demonstrated that people who don't sleep enough were reaching for higher sugar, higher fat foods, and so that sort of with my taste hat on, I was kind of like, oh maybe there's a problem with how their ability to taste food or how they're perceiving the food, and so maybe that's driving these changes in behavior. And so we just started kind of poking around with sleep and seeing if that was a factor, and so now we're interested in how sleep influences food choice, sensory perception, and things like appetite and food reward, all of these things together.

DANNY LENNON: Yeah, and there's so much for us to dig through there, and hopefully we'll be able to work our way through that. But to start by putting some things in context, when we think about sleep curtailment, and we'll get into that maybe a bit later on, but even the idea of sub-optimal sleep which is something that I think many people in the Western world tend to do on a chronic basis, do we have any idea of the extent of the problem or how many people may be getting less sleep than would be required for optimal

health, or how do we think about that question?

ROBIN TUCKER: Right, so insufficient sleep seems to be a really grave public health problem. So one tricky part is we don't have a really good consensus definition of what insufficient sleep actually means, some people would define it as sort of not meeting our current guidelines for sleep which are seven to nine hours for adults, so anything less than that might be insufficient sleep. Some people are really more strict and say it's got to be less than six hours or even less. But depending on how you define it, I would say that the research suggests that anywhere from 35 to 40% of a population may be getting insufficient sleep, and that's a real concern because we know that insufficient sleep is linked to just about every chronic disease that I can think of, when we think about lifestyle diseases like obesity and heart disease hypertension and so on. So on a really big scale, this is a huge public health concern that I think we're only really starting to understand the consequences of that.

DANNY LENNON: And I think one of the things that we'll see in a lot of the sleep research and this will become more evident as we work our way through the methodology of two of your paper specifically a bit later on is different terms that get to describe when we restrict sleep in some way, so I think the three primary ones that a lot of people would see within peer-reviewed literature are sleep curtailment, sleep restriction, and sleep deprivation. Can you maybe just parse out where they have similarities, differences, or how we should define those different types of terms?

ROBIN TUCKER: So you're absolutely right. When we do sleep research, there's a couple of different protocols we might use. So in the case of sleep deprivation, that's where we don't allow people to sleep at all for a defined period of time, maybe it's 24 hours, 48 hours, so on. So that's a total absence of sleep. The work that we do is

more about sleep restriction or curtailment, those are kind of the same things, and it's just where you're not allowed to get maybe as much sleep as you would like. So many of us undergo sleep curtailment all the time or more frequently than we should if we stay up late and maybe watch a few more episodes of whatever we're hooked on at the moment, or maybe we're going to cheat ourselves out of a little bit of sleep and get up early to go to a staff meeting or hit the gym, something like this. So we focus on sleep curtailment as a way of trying to be maybe a little bit more applicable to everyday life. So most adults don't routinely experience 24 hours without sleep. So we've chosen to kind of go in this direction of trying to be more real-life and we're more applicable to everyday people, and seeing if even that is still bad news for some of our health outcomes.

DANNY LENNON: So I think that makes total sense about how total sleep deprivation models can be incredibly useful for highlighting certain things, either mechanistically or even in an outright fashion can be useful for something to mirror what a lot of people are doing chronically, sleep curtailment is probably where we should look at, one interesting thing that you did in the couple of studies we'll discuss today is for the type of protocol you used was different to other types of protocols that some people may see for in sleep restriction studies. So I think with yours, you based it on a curtailment of reducing habitual sleep by a certain percentage versus other protocols might include a time in bed approach. Can you maybe just outline the differences between different types of protocols in inducing sleep restriction or sleep curtailment and why you chose to go with the method that you did?

ROBIN TUCKER: So many sleep studies, if you're reducing sleep, they might choose to go about this as, like you said, a time in bed opportunity, a very popular time in bed opportunity is the four-hour time in bed opportunity which would mean that I

would probably let you go to bed around 2:00 a.m. and then get you up at 6:00 a.m. And we know that you're not going to fall asleep immediately, so it's going to take you a time to fall asleep and then over the course of the night you're going to naturally wake up very briefly. So it's not like you get four hours of sleep in that protocol. What we chose to do, it's another approach, is to reduce the amount of sleep that you habitually get by a percentage, and we chose 33%. This was based on some research that suggests that this is a more realistic curtailment that people might commonly experience in the real world. So we need to reduce sleep enough so that we would actually see, you know, perturb the sleep enough so that we actually see something if something was there, but we didn't want to go so drastic as to just do that four-hour time in bed opportunity. Because depending on how much you habitually sleep, that four hours is going to affect different people differently. So if I normally sleep six hours a night and you let me get four, that's not as big of a difference as if I normally sleep eight hours a night or nine hours a night, and then you only let me get four hours of sleep there. So we kind of tried to make the misery of all of our participants relatively equal, and not penalizing those longer sleepers for their good habits like us.

DANNY LENNON: So if we turn to a couple of those studies that we mentioned, there's one that we will maybe leave for later where you looked at the impact of sleep curtailment on sweet taste perception. But first if we turn to the paper that looked at sleep curtailment and how it impacts, I think there's a whole host of measures here on hunger, food cravings, etc. so with that particular study, can you maybe just give us an idea of what the aim was first of all, and what was the research question you were trying to answer with that study?

ROBIN TUCKER: So we were interested in kind of trying to get at more of a holistic examination of some of the factors that contribute to food choice and

intake and trying to measure them at the same time to get maybe a bigger picture idea of what might be going on that would drive increased intake. So a number of studies have come out and demonstrated this link between insufficient sleep and weight gain or higher BMI, differences in food selection and things like this. So we were really interested to see does appetite change with insufficient sleep, there's been a limited amount of studies to look at that. Most of those studies were done in men only, so we don't know what happens with women. We were interested to see if food cravings would change so we look at how susceptible you are to food cravings, if you're thinking that your mood would be greatly improved if you were able to eat something very tasty. We looked at food reward so how susceptible you were to that and then we looked at portion size selection as well. And all of these factors contribute to the amount of food that you're eating at any one time. And so we looked at all of those things to see if there may be some synergies there that – multiple things are happening to promote increased intake after insufficient sleep.

DANNY LENNON: So if we turn to the methodology for the study, I believe, this was a crossover study, can you maybe just give some of the, from an overview level, some of the basic things people should be aware of how you went about assessing some of this?

ROBIN TUCKER: So first we recruited people who typically met sleep guidelines. So we were looking for good sleepers, really to kind of find out if we just have maybe one night of insufficient sleep, is that enough to cause problems, and kind of spoiler alert it is, but we'd get to that in just a minute. So we brought people into the lab twice, once after a night of their habitual sleep, once after a night of that 33% reduction, and for our participants that was about a two to maybe three-hour reduction in sleep. They came in, in a randomized order, so we were careful about that, and then we asked them to

do the same thing both times. They were given the opportunity to select and plate foods from a buffet that we presented to them, so we wanted to see how much food they would select. We asked them how hungry they were so trying to get a measure of their appetite. We were measuring food reward which is a concept that kind of takes into account the temporary, the current value of a particular food for you, and we measured that with a task where we would ask people how much they were willing to pay for certain foods at that time based on how hungry they were. And then we also had a task where a bit of a modification of a study design that we would use in animals, but we asked them to click their mouse button, and if they clicked it enough times, they could earn a chocolate candy. So those were the types of things that we were looking at when we were measuring the effects of insufficient sleep. We also looked at cravings and whether or not their susceptibility to food cravings changed, so just kind of a whole host of things that if any one of these things could be problematic but if you have many of these things working together you can see where your increase for – the increased risk for overeating certainly is elevated.

DANNY LENNON: So with the food craving specifically, how did you choose to define that for the participants but also what was the assessment for if it increased a craving or not?

ROBIN TUCKER: So we used a validated survey that asked them questions about kind of things about how they would feel if they were able to eat something very tasty at that moment, you know, would their mood improve, would they feel better – these kinds of things where if I'm able to eat something that's very palatable and very tasty, I would do that in order to improve how I feel. So that's a very specific survey for the time right now. There's another survey that you can use to look at sort of, in general, how susceptible you are, but the way this survey is where, if we can look at that exact moment in

time as to how they're feeling about their relationship to food, and especially palatable food, no one really has cravings for celery, it's more about cakes and cookies and things that taste good.

DANNY LENNON: One of the things I found really interesting was the discussion around portion size, and I think in the paper you had highlighted that when people typically serve themselves somewhere around 90% of individuals can consume the entire portion, they end up self-selecting. And so with this idea of portion size, you discussed how it can be influenced by expected satiety and then there's some follow-up stuff that I'll ask about in a moment, but just to get people on the same page, what do we mean by expected satiety and how does that relate to your discussion around portion size?

ROBIN TUCKER: So portion size, kind of the definition that we use is the amount of food that you yourself select to eat. So how much food are you putting on your plate, and that's influenced to a great extent by this concept called expected satiety. And what expected satiety is, is just this interpretation, this calculation that I make about how filling I think that food is going to be, and this is influenced by your previous experience with the food. So over time, we collect data and we understand how this food is going to make us feel and how much I need to eat for how long I need to fill to feel full. And then, so previous experience is important for expected satiety, but also the time until the next eating occasion, so whether that's a meal or a snack. So you can kind of think of this as, if it's lunchtime and maybe you're going to go out to dinner but it's not going to be until 7 or 8 o'clock at night, you're probably going to eat more at lunch to kind of hopefully help you feel full at least until you're closer to dinner. Contrast that with how much are you going to eat if you know that maybe there's a birthday celebration that's going to happen at 3 o'clock and you're fully expecting to, you'll be able to eat some cake and maybe dinner is going to be

at 6:00. So this idea of sort of this calculation that we do, maybe even subconsciously of how much I need to eat in order to get me to my next opportunity to eat.

DANNY LENNON: So we have here this idea of expected satiety which you just mentioned is dependent on the memory we have of previous experiences with certain foods and meals and how filling we might expect that certain food to be, and that in turn influences portion size. So how do those things fit in with a potential hypothesis that insufficient sleep could impact the portion sizes we are selecting?

ROBIN TUCKER: So portion size is to some degree dependent on hunger, so if hunger is elevated, you will probably put more on your plate but then we also know that insufficient sleep wreaks havoc with your memory. And so it's potentially possible that maybe I'm not able to remember as well as I should my previous experiences with these foods and that may lead me to maybe miscalculate how much I need to eat. So I think hunger, working with portion size through expected satiety, all of these things can contribute to perhaps misjudging how much you put on your plate. And then the problem with that is I am very likely to finish what I put on my plate, over 90% of the people who put food on their plate clean their plate. And so small miscalculations throughout the day or if you're chronically getting insufficient sleep, these small miscalculations over the course of several days could contribute to increased intake and then waking.

DANNY LENNON: Super interesting. So with that study what were some of the primary findings on some of those metrics you assessed?

ROBIN TUCKER: So with portion size we found that if we looked at, whether we looked at the meal or snack foods, things like the amount of fat that people selected increased or the percentage of calories coming from fat increased – energy, so calories increased during the meal portion. So these are

consistent with those concerns about increased eating and then leading to overweight. We saw that people were more susceptible to food cravings. So the higher ratings of food cravings could lead to more indulging in those highly palatable high-fat, high-sugar foods. Now, just because you have a food craving, it doesn't necessarily mean that you act on it, but you're resisting those cravings more often, you know, it sort of wears you down over time, and so your ability to resist is compromised. One of the things that I thought was really interesting is people weren't willing to pay more for the food that we showed them so that wasn't something that really changed but they were willing to work harder and eat more chocolate candies. So we saw that they were willing to push that mouse button and do that work and eat more chocolate. So that suggests that the rewarding properties that the chocolate were more desirable, more interesting to people, such that they would go out of their way to make sure that they were able to experience that pleasurable sensation.

DANNY LENNON: I think one of the most striking things, when we start discussing some of these results is to highlight to people that remember we're talking here about one night of sleep curtailment, and I think when you mentioned that 33% reduction and you said that's about two to three hours for most people, so if we take an example of someone sleeping eight hours a night, that's kind of equating to, let's say, for one night, they got to have five and a half hours instead and we're still seeing changes off the back of that. And now we put that in the context of right at the top of the podcast we discussed how so many people are chronically under-sleeping, how much this could compound this issue, right?

ROBIN TUCKER: Right, I think the really scary thing, at least for me, is that we recruited good sleepers, people who told us that they routinely slept seven to nine hours a night, so meeting sleep recommendations, and with just one night of a

fairly modest sleep curtailment, they experienced increased hunger, increased food cravings, they were putting more on their plate and we're willing to work harder for chocolate. That's scary, I mean, when you think about your week, you're trying to hopefully meet those sleep recommendations. But even one night can be a problem, and then if you're routinely doing that, you might think that you're doing okay, you know, oh I really only need six hours of sleep. But you kind of adapt to that and that becomes the new normal and it doesn't mean that you're functioning optimally from a metabolic point of view or a psychological point of view, things like that. So we were really quite disturbed by the fact that with just one night we can see these changes. So the long-term consequences certainly could add up over time and that may help to explain some the factors that contribute to this relationship we see between insufficient sleep and weight gain, obesity, and so on.

DANNY LENNON: And reflecting on some of those findings, what were any questions or future areas that you think started popping up in your mind that you would like to look at next in this area or maybe for other research groups to look at that you think were thrown up by some of these results?

ROBIN TUCKER: Well, I think, like we just talked about, getting people who are not good sleepers into the lab and seeing if this curtailment hurts them, or what might happen if we extend their sleep – so can we recover some of this, how long does it take, is one night of better sleep or longer sleep enough to reduce some of these negative findings or do you need more of that recovery sleep? We also only looked at people with non-obese individuals – there are a lot of differences in both sleep and dietary behaviors between people who are non-obese and people who suffer from obesity that may make this worse for them. And so, we don't know, we're just starting to look at this more carefully, and those are some of the things that at least jump to my mind is future directions for this.

DANNY LENNON: Yes, it's so super interesting. And so, if we turn our attention to the second of those papers where you are looking at the impact of sleep curtailment on taste, perception, and sweet-taste perception specifically, just to start, why did you select sweetness as the taste that you wanted to use to study this relationship between sleep and taste function?

ROBIN TUCKER: So like I mentioned, earlier, I had seen some papers where it said that people were reaching for higher sugar, higher fat foods after insufficient sleep. And so, as a taste researcher, I was curious, maybe there's something wrong with the taste system where people are able to taste food as well as you can if you're well-rested. And so maybe they need more of that particular taste quality to feel satisfied or to get that expected reward that they're familiar with based on their previous experiences with those foods. So we started with sweet tastes as just a place to begin investigating, sweet tastes is widely enjoyed by basically everyone. It's got a pleasant, hedonic perception, so it's something we enjoy eating. Some people more, some people less, but overall, in general, people think that sweetness is tasty. So that's where we started, just to see if there were any problems with your ability to detect sweetness or if perhaps your liking or your perception for sweetness changed after a night of insufficient sleep.

DANNY LENNON: And within that sweet taste perception, there was various different dimensions of sweetness that you measured. Can you maybe mention some of those different dimensions of sweet taste that you measured?

ROBIN TUCKER: So for this particular paper, we looked at sweetness intensity perception – so is it really sweet; is it not that sweet; how are you perceiving the particular stimulus that we were giving you? We also asked about your liking for different concentrations of sweetness and we then also had a particular test where we could

determine your preferred level of sweetness. So we give people multiple concentrations of sweet tasting beverages, and based on your comparison between the first and the second, we have a whole protocol where we can determine your preferred concentration of sweetness. So those were some of the things that we looked at. We looked at taste thresholds previously, a taste threshold is the lowest amount of a taste stimulus that you can reliably detect, it's a measure of sensitivity, and we really found no association between taste sensitivity and sleep. So it's not that you can't taste as well after a night of insufficient sleep. What seems to be changing is your liking and your perception of sweetness after insufficient sleep.

DANNY LENNON: Interesting. You also had a term sweet liking phenotype mentioned within the paper – how would we define that?

ROBIN TUCKER: So I think a sweet liking phenotype – a phenotype is just an observable trait. So we've got kind of a genetic contribution to how much you like sweetness as well as an environmental contribution. So genes and your environment, what kinds of sweetness exposures you receive, all of that can contribute to how much you like sweetness or what your preferred level of sweetness is. So I think maybe this idea of whether or not you have a sweet tooth, some people say they have a sweet tooth, some people prefer more salty things, but it's kind of getting at the sweet tooth phenomenon. So when we give people different concentrations of sweet solutions – as that concentration increases, as the solution gets sweeter, people may respond in terms of their liking of that solution increases. So as concentration increases, my liking increases, and we would call them sweet likers. Now, there are other people where the opposite is true – when I increase the concentration of sweetness, liking actually goes down. So it's the reverse of what we see in those sweet likers, so we call them sweet dislikers. Then there are a couple of

other types of folks who kind of sweet liking neutral people where it doesn't matter what the concentration is, they like it all the same. And then we've got people who like up to a particular concentration, and then it gets too sweet for them, and then they start to dislike those increasingly sweet concentrations. So this sort of separation of people has been shown to be maybe a better predictor of dietary habits when we're looking at taste measures. So we were just kind of curious to see if maybe sleep influenced one group differently or maybe it wouldn't matter at all, so that's why we grouped people the way we did.

DANNY LENNON: Awesome. So with respect to the methodology specifically, again this was a 33% curtailment I believe, but what are some of the basics around the methodology people should know about?

ROBIN TUCKER: Yeah, so same concept as before, we brought people in, in a randomized order, whether after they had slept a habitual night or that 33% reduction. We use an at home sleep monitor that's basically a very, very simplified version of polysomnography which you would use in a sleep lab. This is just a single channel EEG so we can get brain recordings, but it's so simple that people can put it on at home and use it at home and then bring it back to the lab and we can download their sleep data. So we got really good information about the duration of sleep as well as the sleep staging. And that's another thing, again, it kind of told you about my preference for trying to be more real-world and more applied in our approaches, so allowing you to sleep at home in your own bed helps to better recreate a typical night of sleep compared to if I make you come into the lab and sleep in a weird place with lots of wires and things poking you. So that's what we did. And then we brought them in and did our taste testing panel of tests, so we looked at intensity, we looked at preference, and we looked at liking.

DANNY LENNON: And so what were the primary results that you found?

ROBIN TUCKER: Well, bad news, really...

DANNY LENNON: Shocker!

ROBIN TUCKER: Yeah, I know, spoiler alert! So I think, to me the easiest, maybe most accessible piece to take away from this is that after sleep curtailment, your preferred concentration of sweetness went up by about 45%, so that's a lot. And what that might mean is that you start reaching for sweeter foods to make you feel better, to give you that pleasurable sensation, it might be to boost your mood, it might be to sort of recreate what you're used to in terms of when you perceive that food. And so the problem with this is that foods that are higher in sugar or higher in sweetness, I should say, tend to be higher in calories and added sugar. So again, if I'm reaching for something that's sweeter than what I might usually do, I'm probably going to be consuming more calories and that will lead to weight gain. So like I said before, your ability to taste doesn't change after sleep curtailment, at least not after one night, but your perception, your hedonic evaluation, so how pleasurable sweetness is, you need a bigger stimulus to give you that pleasurable sensation, and that's where I think we can – it's another piece of the puzzle of why there's this association between insufficient sleep and increased weight and chronic disease risk.

DANNY LENNON: Sure. Within this study or actually indeed within any study in the area of evaluating sweet taste perception and changes and how that influences food intake, do we see differences between what is causing that sweetness – mainly I'm asking here about the difference between something sweetened with sugar versus something sweetened with an artificial sweetener, for example – is there any differences there or is it simply that there's an increase in sweetness preference across the board, if that makes sense?

ROBIN TUCKER: Yeah. So we looked at both sucrose which is table sugar so just regular white sugar, and we also looked at sucralose which is, you might be more familiar with the trade name, Splenda, it's a sugar replacement product that tastes sweet but it doesn't provide calories. And in general, we saw the same trends with sucrose, copied or repeated with sucralose. So it seems like sweetness in general is something that changes and it may not matter where that sweetness is coming from. This is just one sugar replacement product. There are many, many others. Whether they all behave the same way is a great topic for future research, but the general takeaway is that it didn't really matter, sucrose or sucralose. And that's really interesting because sucralose, the rewarding properties of sucralose, the areas of the brain that are active when you're consuming sucralose compared to sucrose are somewhat different. And so that was one of the reasons why we picked both of those products to test is to see if they would behave similarly, and to a large degree they really did, so that was kind of surprising to us.

DANNY LENNON: Interesting. Robin, I've got a couple of questions that are going to be probably almost impossible to answer definitively, but I'm going to ask you for your informed opinion nevertheless on this. Because so far we've explored how quite clearly there is an impact of insufficient sleep on things related to food liking, food reward, cravings, basically these various different hedonic factors that can impact what we eat. We have others areas of research showing how maybe sleep restriction can see changes in things like leptin or ghrelin or other appetite and gut hormones. So when we think about that relationship between insufficient sleep and then excess energy intake that then can lead on to other problems, is that something that we should consider to be driven more by those homeostatic hormonal factors or by some of the hedonic factors we've discussed

today, or do we have any way to start even thinking through that question?

ROBIN TUCKER: So I think when we talk about the two sort of systems that really drive food intake, we talk about the homeostatic system which is more sort of hunger based, and so I eat when I'm hungry; we say, okay, well, that's homeostatic eating. And then there's eating in the absence of hunger, so I'm not hungry, but I can't walk past that candy dish without indulging in a piece or two or three. And so, that's hedonic eating, I'm eating for pleasure. But I think it's a mistake to think of those two systems separately because they work together to inform how we eat. So I might be hungry, but instead of eating an apple, I'm going to eat chocolate chip cookies. So the hedonic factor of the chocolate chip cookie makes me choose that before the apple, but I'm still hungry, so both systems are kind of working together. And I have to say that much of the sleep research when we're looking at appetite and things like that, has been focusing on the homeostatic system. So we have several studies that have looked at leptin and ghrelin and how those are affected and the responses to those changes by the people that were being tested. But what gets us into trouble I think in terms of food selection and the like is the hedonic system. And again, like I said, whether it's the apple or the cookie, I'm getting more in trouble with the cookie than I am with the apple. And we see again the – we saw hunger change in that first study that we did, so people were hungrier, but they were more susceptible to food cravings, that's more of the hedonic – I'm sorry, yes, the hedonic side of things – they were more willing to work for chocolate which they rated very highly in terms of liking and palatability. That's the hedonic side of things. So I think we have more to worry about from the hedonic side than we do the homeostatic side, because if I only ate when I was hungry, I wouldn't have to worry about my weight. But it’s making choices that might not be optimal and those tend to be really delicious high fat, high sugar, high

calorie foods that tend to get us into trouble. So my wish is that as we move this field forward, we're really focusing on some of those hedonic factors and exploring how those work and then how can we control those or improve those so that people aren't experiencing that increased intake after insufficient sleep.

DANNY LENNON: Right. And so with that whether we see these direct impacts on energy intake, whether we are talking about homeostatic or hedonic factors, there's then, this problem becomes even more complex when we consider there could potentially be indirect effects. So for example, if sleep restriction were to then change someone's behavior around their activity level during the day, that not only could influence energy expenditure but potentially if someone is less active that has an impact on maybe their food intake or their food choices at least or their ability to regulate their intake. So how do we try and consider any indirect effects, if we can, at all?

ROBIN TUCKER: So I think that the nutrition community, and this is where I'll go out on a limb and point the finger at maybe the physiology, the kinesiology community, the physical activity folks, we've sort of looked at energy in, so that's the diet side, and energy out, that's the exercise and physical activity side; and we have just kind of focused on those two sides of this energy balance equation, not understanding that sleep will impact both sides. So the work that we've done shows sleep affecting the energy intake side, making poor choices, choices that are higher in energy, less nutrient dense choices. But we also know from the work of others that while you are staying up later and burning more calories just by being up longer, you are less active, so you engage more sedentary behavior after insufficient sleep. And even though you get a little bit of a bump in terms of calories burned from being awake and not resting, the energy intake side overwhelms any benefit that you get from staying up a little bit later in terms of energy use. So the net positive

energy balance that occurs with sleep restriction or sleep curtailment, that's the problem, and so both sides of that energy equation are affected. And so we need to think about how we can get people to move more and how they can make better choices, understanding that their ability to do that may be compromised if they're not sleeping.

DANNY LENNON: Absolutely, I totally agree, and the interplay between energy in and energy out is one that – I suppose we need to always consider that there is an impact of one on the other all the time, and actually only recently in the podcast we had Mark Hopkins from the University of Leeds discussing some of their work of how at very low levels of energy expenditure and people who are very inactive or sedentary, they have this poor ability to regulate their energy intake through various homeostatic means. And so by changing that energy expenditure side, we have this knock-on impact on what they're likely to do with energy intake. So I think that fits in perfectly with what you've discussed Robin. Before I get to the very final question, I'm sure there are people that are very interested to go and follow up on more work that is being done at your lab and what you guys have got going on. Where's the best places on the internet to divert their attention, or anywhere on ResearchGate they can find in particular papers, Twitter, anything like that, where you would send people who are interested in learning more about what you and your colleagues are doing at the lab?

ROBIN TUCKER: So I am active on ResearchGate and Google Scholar, so all of my papers and posters are there. If you've got any questions, feel free to reach out. Always interested in collaborating with folks and asking new and exciting questions. So those two places are probably the best way to find me.

DANNY LENNON: Awesome. And for everyone listening, I will link up to both of the papers we mentioned in today's episode in the show notes to this

episode, and you'll also be able to find a way to access more of Dr. Tucker's work, both on ResearchGate and Google Scholar, like we just mentioned. So with that, that brings us to the very final question I always end the podcast on, and this can be completely divorced from anything we've discussed today, although it doesn't have to be. So Robin, if you could advise people to do one thing each day that would have a positive impact on any area of their life, what would that one thing be?

ROBIN TUCKER: I think I'm going to stay in my lane and talk about sleep again. I think if you're interested in maybe losing weight or avoiding weight gain, if you want to try to protect yourself to the best of your ability in terms of chronic disease risk, then your sleep has to be a priority. And we've made a lot of efforts and a lot of public health messaging about the time for exercise and making sure you're making time for that. I think we really need to have some of that messaging around protecting your sleep and making sure that you make that a priority to have a healthy lifestyle as well. So I think that message is starting to get out, but it's just like a lot of things, it's hard, maybe you want to be out socializing or, like I said, you're reading a book, or you're interested in doing other things, and we often think of sleep as unproductive time or something that can be caught up on or delayed, or it's not important, and hopefully we can start changing some minds about that and understanding how important the role of sleep is in terms of overall health.

DANNY LENNON: Awesome. Absolutely love that and a great message to spread. And with that, I want to say, thank you so much for your time today, for the discussion, I absolutely loved it, and more so for the work that you've done and that you continue to do to put out this extremely valuable information into the field and advance it forward. So thank you for all of that.

ROBIN TUCKER: Thank You Danny, I've enjoyed it.