092 - humanOS Radio - Vijay Yadav - Taurine on health and lifespan Transcript

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Introduction to Taurine and Longevity

So around 14 months old mice had low taurine levels. And the best way to investigate, whether it is a driver or a passenger of aging, is to investigation the effect of an intervention.

When we supplemented tauring once daily to mice for life, these animals lived longer. The females on average lived 12% longer and males 10%. Not only did they live longer, they were healthier as well.

Because you don't want to be living longer or unhealthy. Hello, everyone. Welcome back to Human OS Radio. Today we are going to talk about a molecule called taurine.

If you subscribe to our Saturday newsletter or if you follow us on Twitter, then you know that we have been interested in tauring for some time. Taurine is an amino acid-like molecule.

And a lot of people might have first heard of it by reading the ingredient list on the back of certain energy drinks, like Red Bull or Monster. It occurs naturally in various foods, including seafood, meat, and dairy products.

But the importance of taurine from a nutritional standpoint is somewhat ambiguous. TAURINE is not an essential nutrient. Humans are able to synthesize tauren from the amino acids methionine and cysteine.

Consequently, taurine is regarded as being conditionally essential or semi-essential. Back in the early 1980s, Taurines started to emerge as a factor in health and longevity.

The World Health Organization coordinated a global observational study in which they performed health examinations on groups of people from 61 different populations distributed around the world.

The researchers measured biomarkers in blood and urine and then followed the subjects for more than a decade to see how they fared. They found that higher levels of urinary taurine, which would indicate greater dietary intake, were strongly linked to lower risks of cardiovascular mortality and explained a substantial percentage of the variants in cardiac events between the studied populations.

Then the research team approached a group who had the lowest levels tauring among all populations studied. This was a group of Tibetans who did not consume fish for religious reasons.

Taurineu2019s History and Early Health Links

The volunteers took three grams of taurine every day. After two months, their blood pressure dropped by an average of 14 points. It has been linked to a plethora of other benefits ranging from improved athletic performance, better blood sugar regulation, reduced oxidative stress, and so on.

And one reason why it's worth investigating taurine, despite not being essential, is that it is possible that the capacity to generate tauring may vary between individuals.

A new research suggests that may deteriorate with age, which brings us to today's interview. Today, we welcome Vijay Yadav to the show. Vijaya is an assistant professor at Columbia University in the Department of Genetics and Development.

He is the senior author on an intriguing new study published in a prestigious journal, Science, on the relationship between taurine and the aging process, which we are eager to discuss.

So without further ado, BJ, welcome to Human Rights Radio and thank you for joining us. Thank you, Dan. It is a

pleasure. What made you interested in taurean in the first place?

Till it was 2012, we were actually investigating what are the molecules that change with age in humans and we performed a large metabolomic study in aged humans.

And what we noted is that one of the most dramatically downgraded molecule in this screen was taurine. I didn't know anything about taurean 13 years ago and I asked my post-docs to start looking into this molecule.

And what we realized is that despite the fact that taurine has been discovered in 1827 in Aux Byles, nothing much was known till about 1950s. and in 1950s pet foods were introduced in society and this introduction of pet food led to variety of diseases in pets.

One of the most striking aspect of this entire episode was that cats started turning blind and so lot of scientists were hired to figure out why the cats are turning blank when they are on pet-foods.

and it took around 25 years for scientists to discover that in fact their diets was deficient in one molecule only and that molecule was taurine. This study was published in 1975 in Science that showed the blindness or retinal degeneration in cats is caused by tauring deficiency.

and 20 years passed by another study was published in science again in 1987 where they showed that the cardiovascular abnormalities also in the cats was caused by taurine deficiency.

Since these events in 80s tauring has been shown to be associated with variety of health parameters and we became interested in taurean because of the levels that were low in aged humans.

You reminded me that my professor during my PhD, Jamie Seitzer, always said that a good scientist is a historian. And I really appreciate the historical account of how Turing became of interest, how we first identified its importance.

I didn't know that, and I'm glad that you shared it with our audience. So let's jump to the study. And the paper has many different experiments described in it.

One of the first things you did was compare serum levels of taurine in humans, mice, and monkeys. How much did the abundance of Taurin in these animals decline with age?

So the different species have a different ability to produce and metabolize tauring. In humans for example, it is semi-essential in adults but it's essential in children when the babies are growing because babies cannot produce it and they need to be supplemented with taurine and that is why baby formulas have tauring in them.

In the cats, they cannot produce the taurine at all. In mice, They can produce taurean to some extent from the liver. So most of these species produce Taureans from liver What we found is that tauren levels decline with age in mice.

Age-Related Taurine Decline Across Species

They went down by around two-thirds. in monkeys, it went by down around 70%. In humans, the levels were declining as we aged. And this is very interesting to us because it says two things.

One, either taurine levels that are declining with age are drivers of aging. That means it actively participates in the process, or it is just a passenger, which is going along for a ride.

I liked your description of that. Why do you suppose that these seromobiles of taurean decline with the age? Do you think it could have to do with endogenous synthesis or changes in dietary patterns as we age.

The answer to that we do not know. There are a variety of contributing factors in metabolism. One is the dietary intake, second one would be absorption from the gut and the third one will be synthesis from liver primarily.

So at the present time we do not know why the levels decline with age and we are investigating into this process in humans as well with the dietary changes and what is the effect of dietary influences for instance in taurine metabolism and its levels in the blood.

So it could be changes in dietary intake, it can be change in absorption or changes of production by the liver. And the answer to that is not no, that would be for future studies.

So what we do see is consistent decline in taurine levels across different animal models. And it does seem to take a major nosedive around middle age.

Next, you performed an experiment using middle-aged mice who were fed either tauring or a control solution. Did taurine have an impact on health after it was taken?

So taurean levels in middle-aged mice are low. So around 14 months old mice had low tauren levels. And the best way to investigate whether it is a driver or a passenger of aging is to investigation the effect of an intervention.

When we supplemented tauring once daily to mice for life, these animals lived longer. The females on average live 12% longer and males 10%. Not only they live longer, they were healthier as well because you don't want to be living longer or unhealthy.

So when we investigated a variety of different health parameters of organ functions, They had a low fat amount, more bone density, better glucose tolerance, muscle strength, a better memory, lower anxiety, and their immune system was functioning similar to younger mice.

And that was very exciting because it told us that overall, the intervention of the taurine improved the health of these animals when they grew older.

So we see evidence that restoring levels of taurean as endogenous synthesis, digeriorates, for whatever the reason is, that decline happens. We see that.

And we then see some benefits that are conferred by supplementing with it. Do you think starting taurine supplementation earlier in life could offer any additional benefits or is it really just maintaining a level after the decline begins?

First and foremost, we do not know at the present time when do taurine levels decline. To give you a bit context, the embryos or during gestation the fetal tissues have five to ten fold higher tauring levels compared to when an animal is born.

I'm talking about humans here. So now it raises a very different hypothesis to be tested. Is it very early on the levels declined?

Mouse Supplementation Improves Lifespan and Health

or it is just the middle age when the levels are declining and old age is having deficiency of taurine. So these questions are important and we are investigating in human longitudinal studies using different ethnic populations to investigate when do the level actually decline.

because different ethnic groups need to be investigated to see whether the ethnicity or different genetic background in humans have different or in metabolic processes which are abrogated because humans are an outbred population.

Africans to begin with but we migrated out of Africa a long time ago and now we are outbred populations. Our dietary changes, our genetic evolution has changed since that event.

So it will be investigated different ethnic groups, different dietary influences in humans. When do the taurine levels

decline? The answer to that we do not know precisely.

I thought that might be the answer to the question, but I wanted to see if you'd discovered any signal that it might suggest that supplementing with higher amounts earlier in life might delay decline.

But yeah, another interesting question to dig into later. So a couple of interesting things here. We know that calorie restriction by itself, of course, is linked to lifespan extension.

How did taurine supplementation influence energy intake and body mass in your experiments? The food intake was not affected by tauring supplementations in animals.

I'm talking about mice only here. And when we looked at the energy expenditure or fat mass, in addition to the food, what we found is that the adiposity or the fat was reduced in taurean supplemented mice.

This reduction in fat mass was caused by a major increase in their energy expenditure. They were consuming a similar amount of food but they were spending much more energy.

So they are burning more. And that led to a reduction of fat. But this reduction happened due to increase of energy expenditures. Because when we investigated what caused the decrease in the fat or later on slight reduction body mass around 8-10%, was that these animals were spending much more energy before the body mass or the fat mass declined to remind our listeners this is in rodents and not in humans although that is the holy grail for many people you can eat the same amount and you're gonna burn more calories and have less fat i will add to that when we look at in the humans low taurine levels in aged humans 60 year old humans is associated with more obesity So that will say that possibly it may have association in humans as well.

So even though that's an association, we do see at least the connection between declining levels and increased sat mass as we age. Another thing that jumped out to me was the change in gastrointestinal transit time in taurine treated animals.

Could alterations in nutrient absorption play a role in the observed benefits? It is possible, definitely, because we do not know the gastointerstellar transit in these tauring fed animals was faster.

So we need to investigate that in more precision whether nutrient absorption or gut microbiome changed to be taurine supplemented mice because we were giving them orally similar to oral pill here.

So, we needed to investigation these aspects more precisely. But nutrient sensing in the cells seems to have been affected because taurean did influence the nutrient-sensing process which gets dysregulated with age in cells.

I found that interesting in the part where we were talking about the influence of taurine on the hallmarks or aging or cellular mechanisms that are altered during the aging process across various organisms.

For instance, cellular senescence is a very hot topic in aging right now. How did taurean affect senesis and the toll on health span and lifespan associated with the accumulation of senus cells?

You are absolutely right. Certain cells accumulated with age. However, I would like to add to this that all the time senescence is not bad for the body.

Senescent of immune cells plays a very essential role in the bone healing process. We need to take senesis with a pinch of salt when we look at the aging studies.

Now when we look at taurine, taurean was suppressing senescence. So with age, the accumulation of senicent cells increases in the tissues to varying degree in different tissues.

And when you supplemented animals with tauren, senisence markers went down in diffrent tissues To investigate whether this suppresion of Senesence by tauring is playing a role, we next looked at Tauren deficient mice and

they had a high seniscence.

Mechanisms: Senescence, DNA Damage, and Inflammation

So to investigate what is the contribution of senescence, we next treated these taurine diffusion mice which have a high senesis with senolytics. because senolytics is going to reduce the number of senescent cells.

What we found was very interesting. Only about 20% of the lifespan of taurine deficient mice was improved. This told us that there are many aging features which might be affected besides senosense which are playing a role in tauring mode of action.

Buck Institute, Professor Judith Campisi was the first guest that I had on the show talking about senescence. She was clear to warn me that even though we're excited about.

the potential of affecting the process of senescence to age better over time, senesis is there for a reason. So whether it's to prevent cancer or helping a process wound healing, it is going to take a while before we can figure out how to do it where benefits far outweigh the consequences of manipulating that system.

And Paul Robbins from the University of Minnesota was on the show talking about it too. So glad to see that taurine could be a valuable player here in modifying the senescence process for better aging.

As you warned, caveats come with this. Thanks for your input there. How about the impact of taurean on telomere shortening and the consequences of telomerase deficiency?

What did you find there? So tauren did not affect the length of the telomiars. It did affect teloma days expression. But in animal studies, what we noted is that if the animals are telomerase deficient and they don't have telomeres, the DNA damage gets accumulated.

If you have more DNA damaged, you get more senescence. It will now supplement these race deficients. In this case, we use fish as a model, zebrafish. You can now overcome the telumerase deficiency induced death.

And that was very exciting to us that you now have a molecule that can overcome the negative consequences of kilomere deficiency in the organism. Very interesting.

Taurine is perhaps best known for its role as an antioxidant. Did taurine impact DNA damage due to oxidative stress? TAURINE had an effect on the variety of oxidatives stress markers.

So you are absolutely right. During the aging process, these reactive oxygen species accumulate in tissues and cause damages to different biomolecules like proteins, lipids and DNA.

And when we supplemented animals with taurine, what we noted is that the oxidative DNA damage was reduced, protein damage by the oxidation species was increased, lipid damage is reduced.

And overall, it was making these cells respond better to these oxidatives during aging. Yes. And I noticed that the supplementation suppressed DNA damage and improved the survival of mice after oxidative DNA damaged.

Not only was there interesting biochemical signatures of less damage, but also a clinical outcome of improved survival. Yes, you're right. Okay. Next marker.

By the way, moving through these quickly, because there was so much that was studied, I want to get to all of them. Inflammation is commonly observed during aging and sometimes referred to as inflammation.

How did taurine affect inflammatory markers? To start with, we looked at different immune cell populations in mice, in monkeys, as well as in humans, inflammatory marker with the taurean levels.

And what we found is that in mice and monkeys, taurine supplemented animals had immune system which had a less inflammatory state. They were functioning more closer to younger animals immune systems.

And they were happy to see that, in humans with 12,000 subjects that we investigated with inflammatory marker CRP, What we noted is that higher taurine levels in humans was associated with lower inflammation in human in each subject as well.

So taurean was making immune system respond better to challenges. How about mitochondrial health? Did tauren have an impact on mitochondria health. One of the mechanisms investigated in our studies was that tauring is actively important in mitochondrion.

Once taurine enters the cells, mitochondria take up a chunk of it. And in mitochondrion, it affects the activity of mitochondrial complex 1. For your listeners, Mitochondrial Complex 1 is a major part of the electron transport chain which produces energy in our cells or ATP.

and taurean was increasing the ATP production in the mitochondry by activating complex one. And that was very interesting to us. And we looked at the mechanism in this paper, how Dorian affects the complex one activity.

Mitochondria have been a topic of interest of mine for quite a long time. Energy production is tied to all other hallmarks of aging. So anything that can helpfully augment energy production seems to improve the aging process in some ways, at least.

I'm glad that it had an effect here. That was great to see. There's much interest now in epigenetic changes associated with aging, did taurine affect DNA and histone methylation?

Depending on the tissue you look at, tauryne had different effects. For example, in the case of skeletal muscle and cerebral cortex, when we look DNA methyltion pattern, Tauryn supplemented old animals, the DNA methalation was similar to young animals.

Meaning the methylation pattern improved. When we look at liver, it did not. It tells us something about the biology of taurine that it is improving the DNA methylation pattern in some tissues but not in other tissues like in liver for instance.

We don't know the reason for this divergence in different tissues response to DNA methylation or epigenetics. We are looking into it is the transcriptome which is having a different responsivity in different tissues.

That is why you have a differential methylation patterns and aging methyltation clock is not well established yet. For blood it's very well characterized but for other tissues it still evolving.

I don't think we have good aging metallation clocks for every tissue in the body at the moment. A new measure of epigenetic age, Elysium as the company indexes the product.

They are trying to advance epigeneic age methylation clocks by providing tissue age levels. So not only getting an overall global biological age estimate from epi-genetic marks, but also looking at a tissue level as well.

Mitochondria, Epigenetics, and Nutrient Sensing

You might have some tissues that are younger than your chronological age and some that were older. I'm mentioning this here to illustrate this point that it does differ between tissues within an organism.

I was a bit surprised that the liver methylation patterns were not altered since synthesis occurs in liver. Maybe that's for a particular reason, actually.

I personally think that taurine is not able to enter liver cells because they already have too much of it. Right. Yes. alterations in nutrient sensing pathways.

This is another hallmark of aging. Was there an impact of taurine on that front? We did look at the nutrient-sensing processes in the cells and what we found is that the tauring was inducing autophagy and it was reducing the protein translation.

So, overall, it is acting downstream of established nutrient sensors. For example, mTOR is a very established neutron sensor. But we find that the downstream processes to this pathway were affected by taurine supplementation.

It improved them. You mentioned that tauring had an impact on autophagy. What is autrophagry? Autophagy is a process by which cells generate small molecules.

This process goes down with age so we are not able to effectively cope with different stressful situations. We have ways to improve autophage. For example, in this case what we found is that taurine is able increase autofaggy and able create those intracellular resources, for example amino acids or nucleotides which can then be utilized for cellular health.

Would some possibly call taurine a fasting mimetic since fasting is one of the most queer and potent ways to trigger autophagy? The answer I do not know because we did not investigate it to be precise, but it did create, for example, it does not reduce food intake.

If it is making a fasting mimatic, It has to do with at the cellular level, But we have not investigated this question. Your study also found a positive effect of taurine on the health of stem cells for their renewal.

Did this contribute to tissue regeneration and any of your animal models? We only looked at two different tissues. We looked the gut stem cell proliferation, and in the skin stem-cell, we found that the number of the stem's cells after a year of taurine supplementation in mice was increased by two to three-four.

And this may contribute to the age-induced decline in the stem cell population or stem-cell health, which can be improved in this scenario. At least in two tissues we investigated, it is improving the regeneration capacity possibly in skin and in gut.

But we have not tested through an induced intervention whether this increase in stem cells health by taurine supplementation is improved regenerative capacity in these tissues.

As we know, when we age our ability to regenerate new tissues does decline. Does this improvement in stem cell activity as seen in skin and the gut? Is that seen elsewhere as well?

Of course, that has not yet been looked at. And then does that actually lead to the regenerative capacity in these tissues, which is going to be dependent upon other factors like inflammation, et cetera.

So because it's having an effect on other hallmarks of aging, you might imagine that This could lead to true regenerative capacity improvements. Then you examined circulating levels of torium metabolites in a large cohort study, the EPIC NOFORC study.

This is in humans. What did that analysis reveal as far as how taurine levels correlate with clinical risk factors? So what we could do is to perform a clinical parameter and taurine and its metabolite level association analysis.

What this tool does is that if you have high tauring levels, you'll have less obesity, less BMI, last waste to hip ratio, lower type 2 diabetes, and less inflammation and liver damage.

So overall, The low taurine levels was associated with poor health and high taurean level in aged human was associate with better health status as far as diseases are concerned.

You also looked at a variety of different types of athlete as well as sedentary subjects. So you had to perform a lot of exercise. How does exercise affect levels of tauren and tauran metabolites?

So, you are correct. Exercise is a healthy state of human being. We were interested if a low taurine level in human is associated with poor health, what will happen to the healthy state of human being?

And that is why we tested the effect of exercise. After a bout of exercises, we noted that taurine and its metabolite levels start up in the blood and that was very interesting because it points to a variety of benefits mediated by exercise taurean may be contributing to this process and of course we have not tested what will happen in people with low tauren levels etc but it does point towards that some of the health benefits of exercise may been mediating by increase in tauring levels in blood.

You intentionally recruited different types of athletes. Did you see differences in responses or different type of exercisers?

Stem Cells, Human Cohorts, and Exercise Effects

It was very surprising that taurine levels increased with all different individuals. In sedentary individuals it shot up, in bodybuilders it showed up.

in marathon runners it show up in sprinters it shows up It tells us probably it's just the effect of exercise. Of course, we have not tested the effect of long-term exercise.

People who are regularly exercising for long term, what will their protein levels or health response would be six months to one year down the line. And that is what we are currently testing.

That's great news. You can choose seemingly your favorite type of exercise, it's all going to have a positive impact. Why do you think physical activity would boost taurine?

This is a very important question with the answer to that we do not know. We don't know whether there is an increased synthesis of taurean from the liver or there's an increase in the release of the tauren from tissues that store it or it is affecting the metabolism of Taureans.

These questions we are investigating why two different exercise individuals had high tauring levels. since exercise elicits a rise in taurine and appears to be more of an acute response.

with a return to baseline shortly after. Would it be reasonable to assume that more frequent bouts of exercise would be beneficial? I kept thinking as I was reading this that perhaps one of the reasons why prolonged sedentary activity is problematic, even if you're exercising enough, we know that sitting too much remains an issue even in that population.

Do you think this promotes the idea of more of frequent bounce of movement? It's very difficult to say based on data that we have that frequent bouts of exercise will improve taurine levels and for that, we need to have a large cohort of individuals to test people who are sedentary or different athlete groups.

Do they have different baseline levels of tauring? And that would require a large population because we had only 35 individuals which were put through the exercise test.

So, and there were males, so it could be sex differences, it would be ethnicity differences. And we need to investigate those parameters going forward.

Years ago, I invented a type of exercise I call Intune training, which stands for integrative and opportunistic. And if we think about how exercise occurs in society, if it occurs at all, it's usually clustered where we do all of our exercise for the day in a workout bout.

And then we go back to our regular life with Intune. The idea is that you're integrating movement into and throughout your day and you do so in an opportunistic fashion.

So you are not trying to overly plan every movement bout, but you might finish an email and do five pushups or 10 squats and then you that throughout the Originally, it was designed to emulate a more natural movement pattern that we see in hunter-gatherer population.

I think it's a very interesting question. Some people have looked at the effect of exercise you pointed out, the hunter populations. There are some ethnic groups which are hunting as a primary source of food.

and you may want to talk to Harman Ponser because he may have more detail about this in terms of how does metabolite levels change in different hunting groups.

So Haraman Pondser is a human epidemiologist and he investigates these hunting populations and glad you pointed out, I have reached out to him and hopefully we would know some details about hunting levels in these populations.

First of all, modern diets may not reflect hunter-gatherer ancestral diets, so we're potentially consuming less sources of taurine in the diet. Then you have changes within absorption levels within the gut.

That's the second place where we might see a deficit occur. And then, of course, there could be changes with the synthesis in liver. So those are the three areas.

dosing. Doses of taurine used in the mouse experiments scaled alimetrically to around three to six grams for an average human size. That happens to near the doses that we see in a lot of the clinical trials that are conducted in athletic performance and blood pressure.

Does that seem like an appropriate amount and does body size matter? So if you're talking about a 300 pound male versus a hundred pound female, does that matter much in terms of getting the right amount of Taurin for a human?

So the doses that we have used in the mouse 500 mg per kg body weight and 1000 mg for kg weight translate to about human equivalent dose of 3 gram per day for 80 kg human or 6 gram for day 80kg human.

and that according to European Food Safety Authority, up to 6 grams consumption of taurine per day is within safe limits. So the dosing seems to be about right.

It is a very plausible avenue that we are currently in. putting together a large clinical trial that we are envisioning to get funding to do the same in humans.

To see, you pointed out also that, okay, if the body weight is higher, would you have a different requirement? It's possible. But also we need to note that it could be that there is a kind of resistance to different parameters.

For example, obesity leads to insulin resistance. So you higher insulin levels, but your cells are not responding to it. So there are different avenues that one has to look at in terms of different populations and different ethnic groups and then we would be able to come up with what is the healthy level of taurine in different groups.

That is when we will know what requirement of Taurin to boost in these intervention trials to get a better health. Taking let's say three grams before bed is not an uncommon practice because of its anxiolytic properties.

Some people find that it helps them sleep better. Would you want to take a total dose and spread that out across the day? Is there some additional benefits there?

Any indication about what you might suspect?

Dosing, Testing, and Future Human Trials

We did that in one of the pilot studies that we did in the beginning. When we were putting taurine in their diet of

mouse to have a whole day consumption.

So mouse ate around five grams. We were trying to get around thousand milligram per day, consumption in this five gram of food that they were eating. What we noted is when they gave once a day dose of taurine to animals, their health parameters were much better improved than animals were given continuous tauring in the diet.

So, of course, this is an animal study here. We do not know what will be the effect in humans. And that is why we absolutely need a clinical trial to investigate these contentions.

I think we would have the answer to this in next three to four years. Is blood testing a reliable indicator of your taurine level status? At the present time, the answer would be that I don't know.

Because meta-analysis of obesity suggests that there could be a state of tauring resistance in obese individuals. The answer will be bit complex here.

That is why we need to test in a large population, in different ethnic groups, different body sizes. What are the healthy levels of Tauring? Because unless we know that level, we would not know.

Let me give you one more example here. Kidney disease leads to accumulation of taurine in the blood. If you have kidney failure, that is how the taurean is being released out.

The kidney is removing excess tauren from the body. and if you have kidney failure or kidney disease, taurine levels elevate in the blood. We need to investigate different disease states in humans and different body sizes, body masses, PMIs and ethnic groups for genetic influences on taury metabolism.

Before we would know a simple blood test which would be able to tell us, hey look there is a low tauren levels for your specific type. And you need to supplement it.

So right now there's not a reliable way to look into this for yourself, it sounds like. I think we will have this answer hopefully in the three years or four years, once we have these intervention studies planned out in humans.

This study garnered so much attention. It does sound like there is quite a bit planned. What are you planning as the next step or steps? So the next step of this research is a randomized placebo control clinical trial in humans.

And we have now partners in different countries, in the US, Germany, Finland, Singapore, Turkey, Australia. The goal is to have an umbrella of clinicians working together with the same set of health parameters being measured in humans to see the effect of taurine on human health and that is a large undertaking because we want to do the study with as best rigor as possible and we are currently putting the steady design in place to start that intertrial hopefully we'll be able to find sufficient funding to those so as well so that it also a major challenge but we're having good hope and a lot of people are approaching to be part of the clinical studies, both philanthropists as well as government funding agencies.

I'm glad to hear that there's a global effort happening, that's there is more research planned, and that it's coming to the point where interventional human research to probe different populations in the study design that offers us the most confidence that you can affect human health.

And what a fascinating line of work. Who knew that the weird ingredient in your energy drink could affect aging. DJ, thank you so much for coming onto Human Rest Radio, talking to me and our audience.

Thank you, Dan. It was my pleasure and thanks to all the collaborators on this project, which brought different expertise on board to address this important and fascinating question for human health.

It took us around 11 years since the beginning to come to this point. And hopefully in the next three to four years, we'll have a better answer for Human Health for Taurin intervention.

Thanks for listening and come visit us soon at humanos.me.