Video Transcript – Webinar: How Humans Survive in Extreme Environments

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Briana Pobiner:
Hi, everyone. Welcome to today's program, How Humans Survive in Extreme Environments, which is part of our ongoing Hot Topic, Human Origins Today topic series. My name is Briana Pobiner and I'm a paleo anthropologist and educator at the Smithsonian National Museum of Natural History. Whether this is your first time joining us or you've attended before, we're so glad to have you here. Before we get started with our program, here's a few housekeeping notes. This discussion offers closed captioning. You can turn the captions on or off via the CC button, which should be located at the bottom of the Zoom interface. As you have questions, please go ahead and submit them to the Q&A box, which is at the top or bottom of your screen, so that we can sort through as many as possible. The Q&A part of the program really flies by. The Q&A box is also where we'll share any relevant links during the program. So keep an eye out there for those.

We'll start with an opening presentation by our speaker, Dr. Cara Ocobock, and then I'll join her here to take your questions. During the presentation, I'll be answering some questions behind the scenes as will Dr. Grace Beach, post-doctoral fellow in the Smithsonian's human origins program. So now I'd like to go ahead and introduce our speaker. Dr. Cara Ocobock is a human biologist who explores a physiological and behavioral mechanisms necessary to cope with and adapt to extreme climates and high levels of physical activity. Her work has taken her from the Rocky Mountains to the Arctic Circle, where she has worked with outdoors enthusiasts, runners taking part in a cross country foot race, and reindeer herders in Finland. Ocobock is currently an assistant professor of anthropology at the university of Notre Dame and a formal power lifter who loves bringing anthropology to sport and sports to anthropology.

She has also organized an and participated in numerous science outreach efforts, including the Human Biology Association podcast, The Sausage of Science. Now, I'm excited to welcome Dr. Ocobock to the screen, and she'll be sharing her screen and slides in order to give her presentation. We're just waiting for Dr. Ocobock to join us again.

Cara Ocobock:
There we go. Hello. Thank you. Sorry, I had to be made a panelist. It just popped up. So, thank you Briana so much for that lovely introduction. And thank you also to the Smithsonian National Museum of Natural History. So, thank you all so much for joining today, and I am delighted to share with you some of my work. I worried at the beginning of this when Briana invited me to take part in this, which I was super excited. And again, thank you so much for the invitation, that she wanted me to talk about humans in extreme climates and only in half an hour. I was like, "How do I do mountains, deserts and blizzards in half an hour?" And so you'll see. It'll be possibly a disappointment, but hopefully you will learn something good out of all of

this. So, as Briana said earlier, my work has started actually in the Rocky Mountains of Wyoming. And this is a picture of me pipeting urine of all things in the bears ears of the Rocky Mountains.

And this was where I was working with individuals taking part in the national outdoor leadership school, as they basically lived and traversed the wilderness for three months. And I had... I worked with folks who did this in the spring and summer and the folks who did this in the fall and winter, and I was interested how their extremely high levels of physical activity and these pretty extreme environments impacted how many calories they expended on a daily basis. And I won't be talking much about that today, but I can give you the long and short of it. They spent a lot of calories in these different conditions, and it was pretty great to be able to work in such a beautiful location. But I have also worked with kind of extreme athletes and these individuals were part of race across the USA, where they ran a marathon a day for 140 days as they physically ran across the continental United States.

And these folks too, had extremely high levels of physical activity and were burning tons and tons of calories. But as part of the sports as was mentioned, I've worked with hockey players, I've worked with cross country runners, I've worked with track runners, and that part of my... And as well as weightlifters as I am one. And that part of my life has kept evolving where my personal and professional Mel together, all the smiling faces you see from the bleachers there are student research assistants who are helping me collect data among the hockey team at Grand Valley State University, and then much more recently, and this was of course the cover photo. I worked in Finland with reindeer herders who will herd reindeer for a living, and they live at the Arctic Circle and above in Finland. And so an extreme environment as well as an extreme activity.

And so humans, we are the ultimate invaders and ultimate adapters. We have been able to inhabit extremely hot and dry climates as well as extremely hot and human climates. And then the exact opposite extreme cold. And this is a picture of a reindeer herder here, but that's not my picture. And then we have also been able to inhabit extremely high altitudes where our ability to get oxygen into our system is greatly diminished and things like technology don't actually help. And so it is quite the work of evolution that humans have been able to adapt to over millennia and millions of years to these different kinds of climates. And then now a much more recent thing that we might start seeing some interesting change ranges to human physiology, though perhaps not on the adaptation level in which this happens over millions of years and there's something that doesn't change, once you have an adaptation, you have it, unless there's another drastic change, but more acclimatization.

So how our bodies respond in a short period of time, such as weeks and months. And that's space. So we have astronauts living on the internet national space station for months to year at a time, and as we look ahead towards perhaps reaching Mars and maybe even colonizing Mars, this is going to be a new, extreme human environment that we have very little experience with. I'm going to be learning a lot along the way, but given my expertise, we're going to turn the hot

topic series into the cool topic series just for one day. So please do bear with me as I talk about my work among the reindeer herders in Finland. And so just to kind of set up the location of where these reindeer herders are, this is a map of Scandinavia where you have Norway over here, Sweden, Finland, Helsinki might be a nice anchor point for you all to connect to, and then Russia off to the east.

And then Rovaniemi, which is right up here is kind of the base of operations for me. And that box has been blown up here at the bottom with a little inset and all of these labeled areas. These are different reindeer herding districts that I have worked with for this project. And so this is a picture from Rovaniemi. This is the Arctic Centre, which is part of the University of Lapland. And as you can see, gorgeous, gorgeous Aurora Borealis that you can start seeing in October and through the winter, as long as the skies are clear and a beautiful viewing area there as part of the Arctic Centre. And then this is a picture during winter feeding among reindeer herders in Oiyvanki. And as you can see, it is cold, it is snowy, lots and lots of fun things going on as well as a pretty demanding job.

And then of course this work does not happen just with me and me alone, it is the result of a wonderful collaboration with the University of Lapland and the Arctic Centre, as well as the University of Oulu. And these are my two main collaborators, Minna Turunen, who is in the red and then Päivi Soppela, who is in the green. We have been working together for six, I believe going on seven years now, working on this project. And it has been an absolute delight to collaborate with them. And so the reindeer herders, let's talk a little bit about them. So in Finland, there 7,000 reindeer herders, and they manage roughly 200,000 reindeer. And the number of reindeer that individuals have or herding cooperatives have, that's going to vary, there are very small herding cooperatives and very large ones. The annual temperature mean in Rovaniemi is one degree Celsius, with the winter about negative 11 degree Celsius, and the summer about 13 degree Celsius. And of course, because this is at the Arctic Circle, you also get pretty drastic changes in sunlight.

So I was to talking with my collaborators just the other day, and they are down to less than six hours of sunlight right now. And that'll basically go to zero as they go through the winter and then climb back up. And then the reverse in the summer, you get about 13 degrees as the average temperature in the summer, and then there are periods of time in the summer where you have nothing, but sunlight. A particular thing about me is I actually prefer the darkness in winter to the daylight in summer. So I'm not sure where that puts me on the spectrum among folks. And then the reindeer herders themselves are made up of Saami and non-Saami individuals. So the Saami are the indigenous population across Scandinavia from Norway through Sweden, Finland, and into Russia as well. Finland is great with having reindeer herders be Saami and non-Saami.

Sweden for example, is on the opposite end of that. They only allow Saami identifying individuals to partake in reindeer herding, as part of the demographics about 25% of reindeer herders are women, which means the vast majority are men. That might be changing a little bit

as there's a bit of a reinvigoration of the reindeer herding occupation going on in Finland right now and women are a large part of that. And for roughly half of reindeer herders, herding is their sole occupation. Whereas for the other half, they take up other occupations as well, such as forestry or tourism or professors at the University of Lapland in the Arctic Centre. And their activities vary seasonally. And so this is kind of a calendar reel of reindeer herding activities that my collaborators put together for a couple of publications that we have as well as some other work that they have been doing.

And if we start with just say the beginning of the year, say in January, things are very, very cold. They are feeding the reindeer either in enclosures or in the field. And that is something that has not always had to be done, but due to climate change, there is an increased need to supplemental feed the reindeer and keep them close and protected from predators. And that supplemental feeding will actually kind of last from December through February and into March as snow cover can last from October through to may, depending on the year. And so in the winter, they're doing a fair amount of daily work of just maintaining the reindeer and feeding them. And then they're able to be released out into their summer, their spring and summer pastures, and then come May and June, the calves are born. And then in June, July, they're going to mark the calves. So each reindeer herding cooperative has their own earmark, so they know whose reindeer are whose. Then come July and August, so there's a very short growing season in Finland obviously.

They are making hay as it were, and they're growing forage to feed the reindeer during the winter. September is a fairly calm time. And then come October and November is when the annual herd roundup comes. And then the herders are going to go up and gather all of their reindeer from their spring, summer pastures, bring them back to the herding district cooperative, the enclosure is there. And they're going to do all sorts of things that I'll talk about a little bit later when I talk about the herd roundup in particular. So you can see the activities are varied and there are periods of extremely intense physical activity followed by periods that are actually much more calm. So the things that I am particularly interested in, at least the things that I will talk about today, are some of the physiological and a little bit of the cultural adaptations that we see among the reindeer herders. So the first is resting metabolic rate, and that is the bare minimum number of calories you need to survive if you were just laying on the ground doing nothing all day.

So it doesn't include eating, moving. Nothing, just laying and existing. That's your resting metabolic rate. And then something called brown adipose tissue or brown fat. And this is a kind of fat that burns only to keep you warm. Excuse me, that I will be sure to give you a little bit more detail on when I actually talk about said data. And then total energy expenditure. This is the total number of calories you spend in a day, including all of the things that you do throughout the day. So going to work, sitting at your computer typing, eating, running, exercise, all of that, the total number of calories you burn in a day. And then finally, I'll talk a little bit about some of the cultural coping mechanisms that the reindeer herders use to basically

survive and thrive in an extremely cold, harsh environment and in one in which they have to do their occupation on a day to day basis.

And so you'll see an interesting mix of things going on there. And so I take a little bit of a bio cultural approach as it's called to my work with the reindeer herders, or I should say our work with the reindeer herders. Well, let's start with resting metabolic rate. So resting metabolic rate, there is a known increase in RMR, which is the acronym for resting metabolic rate among cold climate populations as a whole. And so we have all of these ways to predict what somebody's resting metabolic rate is. And it's often based on body mass, or it's based on how much muscle mass you have. We include sex, we include age, we include a whole number of things. And the graphs I'm showing here is resting metabolic work among indigenous Siberians, the Yakut. And so what you would do is you would kind of use the equation to predict what you think the resting metabolic rate should be, and then you would actually measure it to see do they fall above, below, or right at what we expect.

And so the equation expectation here on the graph is shown in the blue line. Males are over here to your left and females are over here to your right. So the blue line is the equation expectation. And all of the red dots are the actual measurements. And then that red line is indicating how much higher above the expectation they are. And we can see cold climate individuals have resting metabolic rate as much as 30% above predicted values. And this is attributed to the extreme cold that they experience. If you increase your metabolic rate, you're increasing the amount of heat that your body produces, which is great because you end up losing a lot of heat to a cold environment. So the body works to keep up and maintain a constant core body temperature. And this has been theorized to be due to an increase in thyroid hormone.

And so thyroid hormone is really important for your metabolic rate, but also for growth and development. And we have seen some increase in thyroid hormone, but it's not broadly measured among cold climate populations, but we do think it's the cause of the increase among the Yakut. And so what about the herders, the folks that I work with? So this is a picture of me. This is in Finland in the Arctic Centre. I'm here in this three quarter sleeve sweatshirt looking thing. And one of the herders is lying here on a cot. His sock is removed on one foot for a reason, it's so we can actually measure body composition. And so that's why that's going on. And he is wearing a special suit that we'll talk about in a moment. So for resting metabolic rate, they come in and they lay on this cot for 30 minutes and I do nothing. They just lay and they rest, and hopefully don't fall asleep because we don't want them to fall asleep.

You actually have a slightly different metabolic rate while you're sleeping than when you're at rest. And then after that 30 minutes of rest, they the mask on, and you can see the blue mask over his face here, which is connected to a unit that is connected to this laptop. And it is measuring how much oxygen this person consumes and how much carbon dioxide this person produces. And from that, we can get how many calories they are burning just by resting. And so this measurement was taken in January of 2019. And so I'll just put both graphs up there right

now. What I found was really weird, really unexpected. So there was a high resting metabolic rate among the herders, but only among females. So the males are here in X's and the females are here in circles. And then the solid line is for females, and the dotted blind is for males.

And we found that females had higher resting metabolic rates than males. Not only when we control for how big they are, because your metabolic rate does go up the more body mass you have, but they were also absolutely higher than the males. And that is never, ever, ever been seen before. And it's really, really unusual. So I also put the how many calories they burn per kilogram of their body mass here in this box plot and females are here and males are here and you can see females have a much higher metabolic rate than the males. And this next graph is going to look... It's overwhelming. I get it. So I'm going to walk you through it. So just bear with me a moment. All the names you see here down at the bottom of the X axis, these are all different equations for predicting somebody's resting, metabolic rate. There are lots, as you can see. And it always becomes a question of which equation's going to work best. And so we kind of look at all of them to see what actually might fit better.

So females are here in the white boxes and males are here in the darker gray boxes. This hash line at zero means there is zero difference between a measurement and what we expect from the equation. So anything above this hash line means their measured resting metabolic rate is higher than we predict with the equation. And then everything below the hash line means their measured resting metabolic rate is below what we expect based on these equations. And you see women fall well above this line every single time, although it turns out we get the best prediction here with the Froehle equation based on body mass. And so women are trending above and they are consistently trending above. But males are not, they're kind of all over the map. You get some who are above this trend line, but you get a whole bunch who are below as well as some who are right at that expectation.

And so the question becomes why? What might be going on that we see this really different sex based trend among the herders? And so this is a hypothesis that needs testing. So do not take this as truth, because it is not. It is me presenting my thought and idea about what might be going on here. So, females might be resistant to thyroid hormone changes, and they may need to maintain a higher baseline. And so here is kind of a rough shadow human outline, schematic of what thyroid hormone does within the body. It is an incredibly important hormone that I had mentioned before that it can increase your metabolism and it kind of maintains your metabolic baseline, but it's also really important for growth and development. And so that's obviously very true for kids who are growing and developing, but it's also extremely true for pregnant women.

Pregnant women need to have an increase in thyroid hormone in order to maintain a successful pregnancy. And you can see that here with this chart. So this is looking at pregnancy 10 weeks in and 20 weeks in, and now I'm going to have you look at this orange line right here. And that's looking at T4, which is a form of thyroid hormone. And you can see this massive jump in thyroid hormone in the first 10 weeks of pregnancy and how that is maintained because the fetus

needs that thyroid hormone produced by mom at that point to elicit growth and development of the fetus. If that thyroid hormone level is not reached at 10 weeks, you often see miscarriages. If there isn't enough thyroid hormone or it isn't supplemented by medication. And so the idea is among reindeer herders, potentially, or possibly even all Arctic populations, we don't know, this has not been tested yet, is that perhaps females in cold climates need to have a higher baseline.

So instead of starting out down here, maybe they actually start out higher up here, I should say. And so they need a higher your amount to actually reach the level needed to maintain a successful pregnancy. So this is why females might be more resistant to thyroid hormone changes than males. But that doesn't answer the question as to why males are kind of all over the map. And there are a couple of things that might be going on that also need future testing. One is climate change. The Arctic is getting hit very hard with climate change. And it's one that's not talked about quite so much. You talk about polar ice gaps and things like that, but not actually about Scandinavian countries where they've seen an increase in annual temperature for the past 50 to 100 years. And they're getting a lot more warming events.

So things are trending warmer, but also there's great technology. We all have amazing warm coats and gloves and indoor heating and all of those things. And Finland has all of those things too. And so perhaps cold stress just isn't as stressful anymore. And so anything that was driving up the need for a higher resting metabolic rate, like the cold stress, that pressure might be disappearing over time. And so that might be why we're seeing a whole lot of variation in the males in this population, but females are much more constrained, especially if pregnancy is involved with thyroid hormone. So the future direction there is we're going to get hopefully more female participants with lots and lots of rescue metabolic rate measurement, as well as a thyroid hormone measurement. So that was the resting metabolic rate. And then somewhat related in some ways is brown adipose tissue. Because as you'll see this brown fat increases metabolic rate. And so that could play a role into these things here too.

I do not study bears, but bears have a lot of brown fat. And this is a bear getting ready for hibernation and kind of just before hibernation. And I'm not sure how many of you are a fan of Fat Bear Week. I am a massive fan of Fat Bear Week. With the National Park Service, they get pictures of all of their... Well, not all, but some of their bears from spring when they come out of hibernation and they're crazy scrawny and crazy hungry. And then they take pictures again in the fall just before they're ready to hibernate, where the bears have literally put on hundreds and hundreds of pounds. And part of that poundage they put on, is this brown fat. And this is a fat that burns only to keep you warm. And this is something that hibernating animals have an abundance because it burns off to keep them warm while they're asleep hibernating during the winter. And so we've known about this in hibernating mammals for a really, really long time, but we've also known about it among human babies for a relatively long time as well.

And so what you see in this kind of weird yellow shadowing on this baby, who has no neck, which is a little bit creepy, I won't lie. These are the areas in which we find brown adipose tissue

under the skin. So you don't see it on top of the skin. It is under the skin. And it overlies areas with some of the major or that you need to keep protected. So the heart is a really, really big one, as well as some of the major vessels that come up and through the neck, but also the kidneys here on the back. So, we've known about this among babies for a while, and we thought that once babies burned through this brown fat, that was it. Humans never got any more, they no longer need it because we actually can do things like shiver to keep warm or put coats on and turn up the heat. Things babies can't do. Babies can't actually shiver yet. And they can't for a little while. They haven't developed the muscle tone and muscle mass to actually be able to shiver properly.

However, in the past 15 to 20 years, we have discovered that adult humans can and do have active brown adipose tissue. And interestingly, we learned about this through studies on cancer. Folks who are looking at how tumors were consuming glucose. So the form of sugar, your body holds onto in stores is glucose. And it turns out some tumors really, really, really like glucose and eat it up like crazy. And so they were trying to get a way to identify a tumor's location based on glucose uptake. And so they would inject people with a radio labeled form of glucose, and they would then go into an fMRI machine. And one, they would find the tumor and they would also find kidneys, because that's your kidneys and the brain because kidneys and brain are also great with using glucose. But they also found folks lit up at the shoulder and here what you would see kind of along the vertebral column, this is where two of your major blood vessels are. The aorta, which is a great big artery.

And then your inferior... Sorry. Inferior and superior vena cava, which are your major veins. And they realized this was brown fat and brown fat was deposited near the major arteries to keep blood flow warm. And then up here along the shoulders, potentially to keep warm as the blood flow going up to the neck, to the brain. And the reason they were seeing this happen in these fMRI tumor studies is that these rooms, the fMRI rooms are quite cold and the person who's in the fMRI machine can't actually move around and stay warm. And so their brown adipose tissue is actually being activated, which was pretty cool literally. And so how do we measure it now? So one, fMRI machines are crazy expensive and you have to get people to the hospital to do it. And it very, very difficult to do, but there's a way to do it in a general lab setting that doesn't require anything invasive or radiolabeled glucose.

And so there's kind of two parts to it. One, you get to see this picture again, in which I fibbed to you a little bit. I wasn't actually measuring resting metabolic rate in this picture when I showed it before. I'm actually measuring brown fat, but it's all kind of part of the sequence of measurements that take place. And then here is me in a really fancy suit, and this is a bomb suit, the literal inner lining of a military bomb suit. And so the outer shells of bomb suits is you may or may not know, are these really big, clunky, almost robotic looking things. And if military personnel are trying to diffuse a bomb in a really hot climate, they can quickly overheat and that can become deadly in a very short period of time. And so they wear these suits, which are

basically a sweatsuit with this plastic rubbery tubing that goes all throughout the suit that then connects to a pump that then connects to a reservoir of cold water.

And so the cold water is pumped through the suit to help keep the military personnel from overheating. But for me, that means I can control cold exposed my reindeer herders, and a pretty easy, convenient way that doesn't get them wet. And I can control the temperature of the water. So I'm not just tossing them outside to get them moderately cold. And so that's actually what's happening in this picture. I'm actually connecting the tubes to the pump, the suit will flood with cold water. I will still measure their metabolic rate because once you get somebody cold and brown fat activates, metabolic rate typically goes up and then I also have this awesome thermal imaging camera that's pointed at their shoulder because their shoulder is a location as you saw in that previous picture where there is brown fat, and then I'll also take pictures of their chest kind of at their breast bone, their sternum, because that's where there is no brown fat.

And so we can compare the temperature differential between a brown fat positive place, and then a brown fat negative place to see if there is activity going on. All right. So, I'll give you the headline now. Is that hearers do have highly active brown adipose tissue. And so these are the... The bright, colorful pictures are thermal images. And I know they can be really, really hard to orient. So, that's what this real image picture is over here. That's actually me in this picture, I was doing this set up for my grad student and doing a study with her. And so this red circle here is the brown fat shoulder area that we're most interested in. And that basically corresponds to where this cross hash mark is in this picture. So here's my shoulder, arm goes that way. And then my neck and head goes this way. My feet are basically going into the screen if you want to imagine it that way. And the picture below is one of the chest. So this is the chest and the sternum. This is the person's neck and the head would be up here somewhere.

So these are thermal images at room temperature. And you can see the BAT positive region and then the BAT negative region. And then you can see the temperatures and the temperature in this black box here refers to what the hash mark is. So this the exact temperature at the hash mark for this individual. You can see the temperatures are pretty similar between the shoulder and the sternum. So then we cold expose and we flood the suit with cold water, and then we take pictures again. And so, one, the cool thing is you can see the water, the cold water flowing through the suit, which is always fun, which you're like, "Yes, it worked." Sometimes the suit clogs up and then you have a whole mess of trouble to get through.

So one, you can see the cold water through, but two, you can see some major changes in the temperature for the exact same locations. So for the brown adipose tissue positive region, the temperature goes up almost three degrees, but then it goes down almost two degrees at the sternum where we know there isn't brown adipose tissue activity. And so that's one piece of evidence indicating there is brown fat among these folks. And then here's the metabolic rate that we see. So on the left with the orange, this is the resting metabolic rate at room temperature, and then the corresponding thermal image, and then here to the right in the blue

is the brown adipose tissue or the cold exposed metabolic rate. And then the corresponding thermal image here on the right. And what we see is an average increase in metabolic rate by almost 9%. And that's quite a big jump.

And a lot of people are quite interested in ways of getting brown adipose tissue to be more active as a potential tool to fight against obesity, but that's a long ways off. So don't get too excited about that, at least not yet. So, that's the brown fat. Everything just flew through. That's the brown fat. So we've covered resting metabolic rate and we've covered brown adipose tissue. And so now I want to about the total energy expenditure, which is how many calories individuals expend during a day. And this happened during the annual herd roundup. So, October of 2018. And so you can see there, reindeer herders literally chasing reindeer in the enclosure to be able to get them calf mark them, so they gather them into these enclosures and then they will return any errant reindeer. So once reindeer are out in their spring and summer pastures, they pay no heed to which reindeer herding cooperative or districts they are a part of. They all intermingle. That's what they do.

And so sometimes a reindeer from one cooperative gets mixed in with the other, and so they look at the ear tag and they'll get the reindeer back to the homes they belong in. So, that's part of it. They will tag any calves that were born, that they missed, they will also inoculate reindeer against various parasites and other diseases that they can, and then they will do a herd separation. So the reindeer to be kept alive and then carried on through to the next season, versus those to be slaughtered. And then they will do the slaughtering and meat cross of those chosen to be called. But again, this is a very highly active period for the reindeer herding work year. And it is cold. You can see active snow falling there and snow building up on the ground. And so, I wanted to measure, and I used a couple of different methods for this, and I'm happy to talk about it if you're interested in the methodology. One is called the Doubly Labeled Water method, which is the gold standard for measuring how many calories somebody burns out doing their thing.

And then the Flex-Heart Rate method, which is a much less expensive, but a really useful tool as well because it also gives you activity in three dimensional space. And so what we found was, one, you can see the measurements from Doubly Labeled Water here, women are, the females are in white and the males are in gray. This is through the Doubly Labeled Water, and this is through Flex-Heart Rate method. We have good agreement between the two measures, which is not always the case, but it was for this population. On average, they were expending almost 4,200 calories per day. That's 4,200 calories per day. That is twice what the average American expends in a typical day. So they are very, very active. And so their physical activity level, which is called the PAL, that's their total energy expenditure divided by their resting metabolic rate, is 2.3. And that's pretty high. That's a fair amount of activity. And as you can see, they are expending lots and lots of calories, but they ate very little during this time.

And this is really an artifact of how busy they are during the herd roundup. They were only consuming about 1800 calories per day when they were spending over 4,000. And again, they

would be working literally 20 hour days during this time. And so they just didn't have time to eat. But of the food they did eat, you can see the macro nutrient breakdown in this pie chart right here. They were eating mostly carbs, but barely it was almost 50/50, or an even split, not 50/50, but an even split between carbohydrates and fat with about 20.5% protein. And I put the WHO recommendations, the World Health Organization recommendations of macro nutrient intake here to the left, where it's just 45 to 65% carbs, 10 to 35% protein and 20 to 35% fat. So it's a very high fat diet. And what they're actually eating to make this diet kind of depended on who they were, the females tended to eat more convenience foods. So hamburgers, tacos, smoothies, things like that all easily available in Rovaniemi, where we were based out of. Whereas the males tended to eat more traditional foods such as reindeer.

The other part of the is, is that the females tended to be younger, whereas the males tended to be older. So we're not sure if this is actually a sex difference or an age difference among this group. So to compare their total energy expenditure or why I should say the physical activity might be really, really important is it might help keep them warm. So what I have here, this is from my work in the Rocky Mountains, among the national outdoor leadership school people, where I looked at how much it would cost to stay warm if people were not physically active. So it's called the thermoregulatory cost. The baseline thermoregulatory cost, if you were not using clothes or activity or external heating devices of any kind. And so obviously you would spend about 14, 1500 calories per day in the cold.

That is a lot. That is a huge amount of calories to be expending, just to stay warm. In a temperate climate, it's a little over 600 calories per day. And a hot is about 200 calories, 220 calories per day. And yes, because you do expend in a hot climate because it actually costs calories to cool off through mechanisms like sweating. So this is the cost of thermoregulation without physical activity. When you estimate it with heat produced from physical activity, because every time you move your muscles produce heat, because your muscles are not 100% efficient. That heat produced from muscle activity helps to significantly reduce the thermoregulatory cost in a cold climate. And so the reindeer herders might actually have higher total energy expenditures in a cold climate if they weren't so physically active. So that physical activity might be a sort of behavioral mechanism to help keep them warm.

And so this is something that I always like to warn people about, that when that paper came out about high total energy expenditure in cold climates, everyone wanted to say, "You're going to lose way more weight if you go and work out in the cold." And these are all sorts of headlines that came out of this. And there was even a big push at least on the east coast for a little while of cold gyms, where you could go to a gym where they keep the temperature at 50, 60 degrees and work out. And they were all promoting, you'll burn more calories because you're working out in the cold. But that's just not true because the moment you start working out, you get warm. And so the whole benefit of the cold gym is just gone. If you wanted to burn more calories, you just sit and do nothing in the cold, because then your brown fat would activate. So

this is my PSA of do not spend an insane gym membership amount of money on a cold gym, it's just not worth it.

It is a gimmick. So, now I want to kind of wrap up a little bit with the cultural cold climate mitigation strategies that the reindeer herder utilize. And so the first thing I want to talk about is clothing. They actually use a mix of traditional and modern clothing, and they choose which to use when based on kind of the the weather conditions at the time. There are certain weather conditions usually kind of hard pack icy snow that's way better for these boots than like the Goretex boots. But the Goretex boots are way better for driving a vehicle because they don't slip on a pedal. And so there is different use of the modern technology and the traditional technology and they will use them interchangeably and in combination all the time to best suit the weather needs.

And it is that deep experiential knowledge that I mentioned here below that informs that decision making process. They also eat warm high energy foods. And so this is reindeer jerky here to the left and then here to the right of that is a really wonderful traditional meal in Finland of sautéed reindeer and onions served over a mashed potatoes often with a side of lingonberry, and then of course pickles are being served. I look at that picture and my mouth starts watering, not just because it's lunchtime for me, but because I miss that meal so much. I haven't been able to go back to Finland due to the ongoing pandemic. And so I cannot wait for a day to return and dig in once more. The herders also use modern heating technology, both in their homes and in their vehicles. They use the chemical hand warmers all the time and that's not an issue.

They also will use modern technology like snowmobiles and helicopters to gather up the reindeer during the herd roundup. Especially if you have a really big herd of reindeer, helicopters are really helpful for figuring out where they are and then even moving them along. And so they mesh together the modern and the traditional knowledge. And it's that traditional experiential knowledge of how to do the reindeer, the best tactics to get them in, while including modern technology, as well as the ecological knowledge. I can tell you, it is really hard to make out landmarks when things are covered three feet in snow. And so the reindeer herders have really deep experiential knowledge of the land so that they can navigate it, even if it's pretty terrible conditions outside. But that is also to say, as they bring in modern technology, they use things like GPS and various apps on their phones all the time to aid them. But they still do use the experiential knowledge as well.

And so, because this is about human origins, I would've felt like a jerk if I didn't somehow bring in something about human origins. And then for me, the natural part of that is Neanderthals, who were a group of individuals, I think they fully and completely interbred with anatomically modern humans. And so I have a hard time calling them a different species per se, but they inhabited really harsh, cold climates for 200,000 years or more. And they didn't have chemical hand warmers or Goretex or snowmobiles. And so we look at physiological adaptations among folks like the reindeer herders and other groups, or any anatomical adaptations to come up

with potential ways that Neanderthals physiologically coped with their extreme cold climate. And so, one thing that Neanderthals possessed was a slightly different body shape and size one that we actually do see among indigenous cold climate populations.

So, a Neanderthal female is depicted here in blue, and then an anatomically modern human female is depicted here in red. And the Neanderthals tended to be short and squat. So, they were broad and they had short limbs, so short arms and short legs. And this was great because it reduces surface area. So it reduces the amount of body exposed to the extreme cold, whereas in hot climates, such as where atomically modern humans kind of first appeared, you want to be long and lean because you can dump heat with that extremely high level of surface area. And so we also see this in other mammals, as well as in indigenous cold climate populations today. So we've got a fennec fox over here, which I just, my niece loves fennec foxes, and she just squeals with the light when she sees them.

But you can see, especially in the ears, this is a really great example of what we call Bergmann and Allen rules. Bergmann says individuals would be larger, higher body mass in the colder climate it is. And then Allen says, your extremities will be shorter the colder climate you are in. And so the fennec fox is a desert animal and has these giant ears to dump heat into the environment, whereas this adorable Arctic fox has teeny tiny ears to conserve heat and not lose it to the environment. And so there's the potential among these anatomical features that we see with Neanderthals that perhaps they were also, they had abundant brown adipose tissue activity. That is a possibility as well as this really interesting combination of physical activity to help keep them warm. We know Neanderthals were highly physically active and moving around in hunting, and that could have been really beneficial to their ability to stay warm, despite extremely cold environmental temperatures.

And so moving forward to learn more about the reindeer herders, and then try to apply that as much as I can as there's always big room for error when you apply things back to the fossil record about Neanderthals, the focus is going to be much more on climate change. So the Arctic has been undergoing and seeing the effects of climate change for quite some time now. And in the past 50 to a 100 years, Finland has seen increased mean annual temperature, a shortened snow season, an increased number of freeze-thaw days, and an increased number of extremely warm weather events, as well as extreme ice events. And so I know this is an eyeful up front and any theoretical model is always going to be an eyeful when you take a look at it, but this is kind of what I'm working with for moving forward with this project where I'm very interested in how physiology and culture interact and how especially the Arctic environment puts pressures on those, and then how the culture and physiology too might be responding to the Arctic environment and even impacting it.

And then at the dead center of this is the big thing of climate change. How is climate change affecting folks physiologically, culturally, and then the environment, and then how are all of these things interacting together to then somehow affect resilience. And resilience in this case is how successful someone's livelihood is, as well as how good their quality of life is. And so

we're very interested to see how these things are interacting and changing among the reindeer herders to see how it's impacting the livelihood success of reindeer herding, also fishing. There's a big fishing culture in Finland as well, but then also how it might be affecting the of life. So mental health, physical health, and even demographic trends. Are we getting more reindeer herders, or fewer reindeer herders?

So this giant beast of a model is where things will be moving in the future if grant funding comes through. And I think it'd be really exciting and very informative as a way of how do the reindeer herders cope with their drastically changing environment and how can we maybe implement that on a broader scale elsewhere? And so with that, that is kind of the end of the talk part of this for me. I'd like to thank all of these people and funding agencies and collaborators, because good science takes many villages to do and to do well. So, I will stop my share and we can go from there.

Briana Pobiner:
Fantastic. Thank you, Cara. That was a wonderful presentation and we have a ton of questions that have come in, so we'll try to get to as many of them as we can.

Cara Ocobock:
Great.

Briana Pobiner:
I want to start with a great one from Granbury Middle School. And they asked, why do people herd reindeer?

Cara Ocobock:
Why do people herd reindeer? So hello to the Granbury Middle School. Thank you so much for joining today. It makes me so happy that a middle school is joining. I shouldn't waste time with that, but still super happy. So there is a very long, long tradition of reindeer herding, and you can kind of think of it as cattle ranching here in the United States. It's the same kind of thing that it started as a source of food on a much smaller scale. When there weren't big reindeer herding cooperatives filled with thousands of reindeer, it would've been on a much smaller scale for families or slightly larger family units, and they would herd reindeer to have a consistent source of food. And so of course now things have been blown up to be much, much larger, and they not only have food for themselves with the reindeer herding, but they sell it.

And right after the herd roundup, the reindeer herders are busy selling and delivering the meat from the slaughtering process. And my collaborators even say, "Yep, I'm going to get my X number of pounds of reindeer meat for the year, right after the herd roundup." So now it's like a commercialized business, but there's also a long tradition, a cultural tradition, which is we're seeing a resurgence in it now. There was a time where the number of reindeer herders was in decline, and we're seeing a resurgence of people trying to bring back and kind of enliven that culture. And this is where we're starting to get more women in reindeer herding. They seem to be kind of at the forefront of not only the reindeer herding, but carrying on the tradition of

learning how to make the traditional clothes that I showed you pictures of, because that was... That knowledge was starting to disappear. And so we're seeing that kind of go up again. Thanks for a great question.

Briana Pobiner:
Yeah, great. Here's a great question from Neils who asks, is there any genetic similarity between humans and reindeer as it relates to cold adaptation?

Cara Ocobock:
That is a great question. And I have no idea because we're learning this stuff now. And so we do know that the reindeer herder in Finland have brown fat. We know this. We are only just of getting the genetic side of things incorporated into it. And it's actually going to be far easier to do among the reindeer than it is among the reindeer herders. So the Saami, the indigenous population across Scandinavia, there is a deep and troubling history of folks coming in and doing kind of abusive research among... Because they were interested in cold climate adaptations and there was not exactly things like informed consent and they had school children keeping their hands and buckets of ice for long periods of time to get a piece of candy. These kinds of things. And so there is always deep discern when we work with indigenous populations and collecting blood and collecting genetic data.

And so there's a lengthy ethical process to go through. But even beyond that, there's a lengthy process of just working with the population themselves to make sure they're comfortable and they want this study to be done. And it's not just, Cara Ocobock from South Bend, Indiana stomping through and demanding data. That's not how it works. You have to do this co-creation of knowledge.

Briana Pobiner:
Thanks for bringing that up. I appreciate that. So, and you talked in the beginning of that answer about brown fat. And so we have two questions that came in about brown fat, excuse me.

Cara Ocobock:
That's okay.

Briana Pobiner:
The first is from Granbury Middle School who asks if children tend to have more brown fat than adults. And then Jason asks, does one gender have more brown fat than he other?

Cara Ocobock:
Oh, you all are asking all the wonderful questions that I'm asking. So because brown fat, we've only known about it in humans for 15, 20 years or so. We don't have a lot of data. We have actually very, very, very little data to work with right now. And it's now becoming a big... Oh, here we go. Hot topic. I have brought back the series title in, we are no longer in the cool topic, we are in the hot topic series again. It is a big topic right now, not only within anthropology, but

also within the medical fields because of that potential link to obesity. So, we don't have a lot of data on non-baby children, the best way to do that. So the juvenile period, once they stop being an infant through the juvenile period, we don't have a lot of data.

Although colleagues and I just had a paper come out about brown fat among babies testing the exact same methodology that I showed you today on babies, which has not been done before. And I can tell you it's hard because babies don't hold still and they don't like being cold. So it's a very difficult thing to do. And so as for the absolute amount of brown fat, that's another really difficult thing to quantify. And so we need to come up with some better, kind of 3D internal imaging measures of brown fat, which we just don't have a noninvasive way to do just yet, but we're working on it, collaborating with a person over in engineering about possibly coming up with that. And as for the sex difference. So maybe. Right now with the little data I have, and there's going to be populational variation, there's never going to be one rule that rules them all.

With the data we have, women might have more. It seems that what we're seeing that women might have more, that among, and I should say females and males, what we're seeing, there is more frequently a tendency and an odd tendency to see a metabolic rate drop during cold exposure. And there's a couple of different reasons for it, and we don't know why we might see that more among males than females, but these are things that we are exploring right now.

Briana Pobiner:
Very cool. So I'll keep on the brown fat questions. There is one from Abigail, who says, pre-health major here. Is there an equally high benefit to humans having brown adipose tissue, even in more moderate climates, or is it exclusively beneficial in more extreme temperatures?

Cara Ocobock:
Yeah. So, this directly relates to my graduate student Alexandra Niclou's work. So she did brown adipose tissue measurements in Albany, New York, which is... It's a temperate climate. It's highly seasonal. Nothing... Well, there are extreme days I will say, in Albany. And we found brown adipose tissue among folks there. And these are not folks who have cold climate, any ancestral connections whatsoever, they've been in Albany for generation upon generation, but it seems there might be a seasonal increase in brown adipose tissue in say winter. And it might also even become a little bit more efficient in that if you are cold in summer, say the AC is on too high in your office building or something, your brow fat might turn on and you're going to burn more calories, but it looks like people might become more efficient in winter as brown fat is turning on more regularly with the cold exposure.

And also my grad student, I love Alex so much and I'm insanely proud of her every single day. Her dissertation work is among some moans, which is an island tropical Polynesian population. And we're seeing brown fat among them as well. And so this might not be something there's some interesting things about the people of the Polynesian islands that would've required cold exposure during long overseas journey. So there might be a cold pressure that happened in the past, but it's still there because we're still getting brown fat, even in a tropical population.

Briana Pobiner:
Fascinating. We'll stay tuned to hear more results from that research.

Cara Ocobock:
You'll see. Just invite her on and she can talk about it.

Briana Pobiner:
Excellent. I'll do one more question on this line and then I'll switch to another line. So Martin says, thank you for the excellent lecture. I was surprised about the 9% increase of metabolism due to brown fat. I've heard that it probably burns only a few killer calories, could part of the increase in metabolism and in your measurements be due to shivering?

Cara Ocobock:
That's an excellent question. Absolutely excellent question. So absolutely it could. However, we watched out for that. Because we know. We know going into it, that shivering is a thing that can happen in some population. So the Albany population was much more likely to shiver. I think I only had two folks shiver among my reindeer herding population. So there's an interesting question in and of itself of what this threshold for shivering actually is. And because we are monitoring for it, the moment we see shivering go on, we mark it in the metabolic rate data, and then we warm up the water to get them to a point where they're cold stressed, but not so cold stressed that they're shivering. And then once we go back and look at the data, we've marked where the shivering happened, we take that out so that we're not actually including it when we do the calculations.

Briana Pobiner:
Oh, fantastic. Thank you.

Cara Ocobock:
Mm-hmm(affirmative).

Briana Pobiner:
So we have a couple of interesting questions from Walter that is more about sort of population differences. And so the first one is with this extreme environmental stress, is life expectancy lower than that for humans living in temperate or equatorial climates?

Cara Ocobock:
Ooh, that's going to be very population based. So one thing I will say is Finland's got socialized medicine and great healthcare. I was a beneficiary of that amazing healthcare when I was there. I had an emergency situation that I had to go to a hospital, I was seen very quickly. And I think I paid like 50 euros. Fantastic. And so I feel like life expectancy might be far more closely related to things like that than necessarily the extreme cold that they are looking at. And so we could easily find cold climate populations that do not have the infrastructure that Finland has. And I do not know offhand, but there are a number of indigenous groups who are horribly, horribly

underserved when it comes to healthcare. And I think that is a much higher driver of differences in life expectancy than just the extreme cold itself.

Briana Pobiner:
Yeah, that's a really important point. Thank you. He also asks is premature birth a problem for the female reindeer herders?

Cara Ocobock:
Not that I'm aware of. So this is something that we've been looking into. And it'll be a little bit of demographic data as well. And then questionnaires and things like that to kind of like, is this actually a link or have I just made up this entire theory out of whole cloth? Typically, in cold climates and the work I'm about to cite is a little bit older and it's from indigenous Canadian populations. That premature birth is not a thing, but large birth sizes. So big babies, babies are born quite large and that can lead to its own set of complications at birth. If a baby gets stuck and you don't have proper medical healthcare to deal with that. So about premature birth, I do not know, but that would be fascinating also trying to understand what the miscarriage rate might be and what if that is linked to thyroid hormone as well. Those are all questions I've got written up for grants in the future.

Briana Pobiner:
Excellent. Last question from Walter, regarding human metabolism and wellbeing, is this population overweight?

Cara Ocobock:
Oh my goodness, yes.

Briana Pobiner:
Is there a significant incidence of cardiovascular disease or stroke?

Cara Ocobock:
Thank you, Walter. So I left this out because I actually recorded a lecture for somebody else this morning and the whole thing was about the health. And so it was a great question. So, 75% of the herders I worked with, 75, were either overweight or obese. So they're big. They do have a good amount of muscle mass, but they're also over fat as well. So they have a high degree of fat tissue along with muscle mass. So yes, they are large. They tend to be on the large size, which is not wholly unexpected given these patterns we see with cold climate populations both past and present.

And so there's that. Overall in Finland, Finland has some of the highest rates of cardiovascular disease in the world globally. And that is starting to go on the decline now, because there's been a big push to limit saturated fat intake. So, there's the potential that there could be some sort of genetic predisposition to it, but there is also the environmental and cultural factors of processed foods, so on and so forth. So the herders, I did measure glucose, total cholesterol, HDL, LDL cholesterol, and triglyceride levels. And despite the fact that 75% of them were

overweight or obese, their blood biomarkers are more or less normal, which completely bucks the trend you would expect for folks with high BMI, you would expect really high, out of whack glucose levels, really high cholesterol. They do tend. The average is within the normal range, but there are folks who trend upwards, but the upward trend in cholesterol seems mostly driven by high HDL cholesterol levels.

And HDL is the good cholesterol that you want. They have amazing HDL cholesterol levels. And part of this is likely due to the consumption of fish of which there's a strong fishing culture in Finland and the consumption of wild reindeer. They're not fully domesticated, they're semi domesticated because we actually do see fat content differences between wild animals and domestic animals. So, that could be part of it. But like I said, the reindeer herders are also crazy physically active. And physical activity has been shown to mitigate any negative effects that are associated with overweight and obesity. So there might be this really interesting confluence. This is another theory I have going on. This really interesting confluence of three things. The potential that there could be a genetic propensity away from issues with poor health associated with high fat, and that could be due to cold climate adaptations. So there's a metabolically healthy obese phenotype, cold climate adaptations and high levels of physical activity. And these three things could be working in conjunction to help keep the reindeer herders within a pretty normal cardiometabolic healthy range.

Briana Pobiner:
Very cool.

Cara Ocobock:
Now I'm sad I didn't include those slides. I feel like-

Briana Pobiner:
No, it's great. It's great that these questions are coming up. We only have time for one more question and then we'll wrap up. So Marilyn asks does sunlight affect thyroid production?

Cara Ocobock:
So, this is a thing that we need to look into. So more and more we're getting into studies, looking at what light exposure actually does. And it does a whole lot of things is the answer. And then trying to work out those actual mechanistic pathways, that's a whole other can of worms entirely, but that's something else that I wanted to look into. So the heart rate monitors that I throw onto the reindeer herders, they're also light monitors. So if they're wearing it somewhere where they're exposed to actual environmental light, I'll be able to get data on activity, light exposure, and then see what we can tie to resting metabolic rate thyroid hormone. But of course this needs to be done seasonally, not just during the reindeer herding, the roundup like I did for what I presented to you today.

Briana Pobiner:
So much more left to uncover.

Cara Ocobock:
So many questions. Give me money.

Briana Pobiner:
Exactly. Work like a true scientist. Okay. So thank you everybody. This concludes our virtual program for today. Please join me in thanking Cara for sharing her work with us. I'd also, once I clear my throat, I would like to give special thanks to those who made this program possible to our behind the scenes team who helped sort through your questions, to our donors, volunteers, and viewers like you. And finally, to all our partners who help us reach, educate and empower millions of people around the world today and every day. We thank you. We are taking a break from our monthly Hot Topic program series in December, but we hope you'll join us in the new year for our January event. We've put a link in the Q&A where you can find information about our upcoming programs and how to sign up for the museum's weekly e-newsletter, that's really the best way to stay informed on upcoming programs and to learn more about the museum's research and exhibitions.

Right after this webinar ends, you'll see a survey pop up, asking for some feedback about the program. Please take a moment and respond. We're very curious to know what topics you might be interested in seeing for future programs. And we appreciate your input. Again, thank you to Cara, to the participants and to all of you in the audience. And we'll see you next year.

Cara Ocobock:
Thank you, all.

(End of transcript. Return to the web page for this video, How Humans Survive in Extreme Environments.)