Ernest K.: Say good morning.

Audience: [inaudible 00:00:03].

Ernest K.: I have the UK time, so it's after. Thank you very much for the introduction and now you can dismiss some of the things she said because she's just making things look good. I'm Ernest Kamavuako and I really thank you, and I'm pleased to be here. Great work. I know JR and Nancy. I've been invited places before but the care that was preceding this moment was incomparable, so quite nice. And then they send you everything, all the details. They prepare even... They tell you even how long the taxi will take from [Guardino 00:00:46] to here. That's good. And thank you very much. And I'm really happy to be here.

And one thing is to discuss and talk to engineers. Another thing is to discuss and talk with clinician. And when we have talk with engineers we try to [inaudible 00:01:05] with numbers, with formulas. So that's the presentation phase, good. But then we are here to discuss and talk with clinician and then you need now to weight the balance of what do you present, so you still give meaning.

So my talk today will just cover four pieces. I will talk a bit of my research just to put things in context and why I work with Heidi and the Co-Op in New Zealand and then I will discuss a bit of [inaudible 00:01:37] detection and measurement method that we use, as well as using high density EMG. And then a very specific study that we did together, with Heidi and coauthors, where we did one part in Aalborg and then another part was in New Zealand, in Oakland. That's that day where I wish my transit time at the airport was longer because I flew from Copenhagen to Singapore for 12 hours.

I only had two hours to change the plane and take another plane from Singapore to Oakland for 10 hours, stay there for eight days, didn't have the change to adjust, and then 24 hours again back home. Now I know they inviting me, I'm trying to delay this invitation as much as I can so I don't have to lose 12 hours of my life. If you go to New Zealand, you have to come back. If you don't, then you lose 12 hours of your life. That's the truth.

So just have the perspective, to be fair, I'm a biomedical engineer, so a focus more on the engineering side and then I usually open mind. If someone comes to me, I like the idea, then we go for it. As long as I know there's a need out there, then we go for it because everything we do start with an idea. You may think someone is crazy but then that might become the best idea in the world. So I listen and then I take action when I see I can contribute.

So currently I'm in the UK as a senior lecturer, King's of London. I'm also responsible for the engineering education. We just started a new department. And then I'm head of the laboratory for myoelectric control and health technologies in general. I used to work in Aalborg, until two years ago, then I left to take a permanent position in the UK.

So King's College, for those of you who don't know, founded in 1829, one of the top 10 universities in the UK, in the world classification. We are really in the center of London where anything happens. Sometimes if too busy because now we have two buildings for the Strand and then just close to the Waterloo bridge. So they sort of lot large traffic of students, we have with 30000 students crossing that road every day. So now the council is planning actually to shut down for traffic and then make it like a walking straight, which will be nice for us and the student for facility.

So out of the nine faculties, I belong to the faculty of natural science and mathematical sciences. And then I am in the engineering department, which one of the five department in the faculty. Within the department, we look more into wireless technologies. We have one of the best 5G labs in the world and then we are too focus group, clear communication. And I belong to the robotic group and because department is quite new, we are now trying to grow and then trying to touch different aspects of engineering.

But within the center of robotics we touch different aspects of robotics. I focus mainly on the use of muscles. And then this was an exhibition we did in Science Gallery in London. And some of my colleagues, we look at different aspects of robotics. We have those who have really focused on mechanical part and the others are much more in soft robotic. And that's when you are in such a diverse area and then you are coming with some knowledge of biology, then you have many people to collaborate with also across the campus in general.

So my research interests, I'm a bit polyvalent, so I mainly focus on functional restoration for amputees. And for that we use muscles, either from the surface, but mostly from inside the muscles, intramuscular EMG and then try to understand what the brain is telling us. I call it to speak Brainish because the brain doesn't speak British or English or French.

It speaks Brainish and Brainish is a set of stacks that comes after each other, modulating the frequency and then to tell us what the brain want to say. That way, if we also want to tell, there's a typo here, it were meant to write Brainish and I wrote British. If you also have to tell the brain something, we have to learn how to speak Brainish. How do you code enough information to the brain so the brain understands that the amputee feels pain or anything else.

But everything comes around using health engineering in general and focusing mostly on how do we then capture the information from the body. So I see the body as a system, as a aerospace or mechanical engineer, will see a model as a system. So one of the topics we are focusing now is hydration and we are actually working on a system where you can just place a bunch of sensors on the body and then tell someone exactly how much fluid they take. So for each sip they take, you can calculate the amount of, or the volume of fluid and this is basically just to prevent the episode of dehydration. We don't want to measure dehydration because when you can measure it, it's actually late. We want just to make sure that elderly, or in England to say older people because

elderly is not good to use in England, so older people can keep a track on how much they drink to prevent dehydration.

And then what the focus area is also on cardiology. I have the opportunity to go back in Africa to do some teaching and then when you visit hospitals over there you see how things we actually take for granted are luxury in those low income settings. So we are trying to develop a device, a ECG and PCG SPU 2 device, that should cost less than 100 pounds, so that it can be affordable for low income settings, providing very advanced machine learning that actually can tell the doctor if the patient is high risk of being sick or not. And this is [inaudible 00:08:53] development. So far we have already developed our own electronic stethoscope and all the components we use has cost us 10 pounds. So we are still in the budget to reach the 100 pound or keep it below that.

But then I see applied biosignal processing in general as my thing, and my interest. Everywhere where I can come and contribute with acquisition processing, then of course I will be... You should come to me, we'll talk DNA. Then I will say, "I can't do that." But then if anything that is apply biosignals, then I can be on board and I'm usually open minded.

So from an engineer point of view, we are interested in input output systems. So we have a system, we have the input output then in many cases we don't know that black box what is happening. So what we want to know, if you have something from the input, you know the output, and then how can you then make sense of the process that is going on to transform that input into an output.

And the basic one, we have our mic, I'm speaking to this thing and then suddenly you can hear it somewhere in the building and the process is easy from the engineering point of vie., What you do, you do reverse engineering. You find out, "Oh basically we just have something that is amplifying my voice." Other basic ones are computers that we use every day. We have input and then we the output on the screen. And then that's how we then see the body. We have the smell. we have the ear. And then the brain. We process those input and then there will be some kind of output.

In this case I can say I smell coffee, I smell tea, or the taste is good or bad. It's just one output from the body. While we have a lot of input and then your brain which is a super machine, we than have to process all the things as quick as possible to make sense of what is coming in the body, but then from a bioengineer point of view, I will not look at the computers, I will look at the body as a system. And the body will have an input and then will provide some output.

And our body is nice because we have so many different output. I'm speaking to you. I will move my hands. I can move on the stage. I don't really care so much how I'm moving, but my brain is doing something trying to make sense of my movements so that I don't trip, then I keep balance. So what then... When I was assessing with Heidi what if then we replaced that input with chiropractic adjustment. So we closed the eyes, forget all other input. We focus on chiropractic adjustment as input.

So we are doing something or not me, you are doing something. I'm just watching and then of course different assessment or some kind of output that we have. This could be that the patient is working better, it could be the patient tells you I slept better, or now I can easily eat because I've appetite and then all those kinds of inputs that can be into the different assessment can we then reverse engineer and can we understand the process that is going on so that our input actually make sense and find the relationship between the input and output with the body as a system.

So that's how my approach to chiropractic. So if she says, I don't care, it's I don't care because when we do this, she's out of the equation. I will look at the data myself. Because I don't know what to expect. I would just show them this is what I found. What do you think? Is it good or bad? Or it's good and then why do we see that? And that's the good thing of being a bit outside, then you don't have a bias toward a kind of one particular output that you wish.

This slide from [Verywhile 00:13:10] shows, I don't know if it still... It might be old common wisdom because I saw lots of other reason that Heidi showed but at least the message here is that by having someone, a chiropractor, touching the body, moving your body, we are sending something into the body. That's the fact and that is known and then we have now to look at the output.

So we have clinical output, functional outcomes. You may look at how your blood rates or so your heart rate is changing or your blood pressure's changing, or you might look at whether the patient is walking better because one thing is to say we have a significant difference in the velocity. Another thing is, is the patient really feeling that it's clinically viable? And of course then what are the process that is actually making those to happen, and then in which aspect I belong, so I will not focus too much on the functional outcomes. I will mostly focused much on the clinical outcomes that based on biological signals, things that I can measure, I can look at on screen, I can see if it's doing something, if it's changing or not.

So then if you go back into the system engineering... So remember you have the input, you have the output, the process, and then as engineer we talk about transfer functions, so how are we transferring our input to get some output. And then you will find a lot of mathematics behind that kind of thinking. Some of us trying to map the neural network of the brain and then trying to put it into numbers and make sense of the output. So in my case then we replace inputs by chiropractic adjustment and then we have an output, as I say, could be different output. I focus upward on the biosimilars that I get. And then the question is, what are the transfer functions that are within the body that give us the output we have? Does it help us to understand better what actually we are doing while we are adjusting the spine?

So when I see this one and I think about it... When I moved to London I didn't like it because the wife wanted to move to London and then happy wife, happy life. So you start to understand and then now I start to like it. Although you still sit in a train and they will say also with the council take alternative route because there are people on the tracks. So what are you doing on the tracks? Supposed to be home. So I see it as

London traffic. In London if you see the highway... When I moved there first time, when I see traffic jam on highway, I will try to find alternative route.

It's like the spine. When the spine is blocked all the peripheries are blocked as well. So in many cases when you are not patient in London, you leave the highway for side route, you end up spending more time. For now I've learned, unless the highway is completely blocked, I will just wait because everyone else is thinking exactly like me. They will take the peripheries and then when you go there, you get again your jam. The same way, if you adjust the highway, then you also make a relief on the periphery. If should go for the spine, you make the spine feel better, and rest of the body might feel better, especially if you're on the North Circular Road that provides the ring around London. When this is blocked... And London is structure really bizarre. You can't really get straight routes within here. So they've made it very difficult for people to just leave the North Circular Road and then [inaudible 00:17:43] because they need to protect the [inaudible 00:17:45] here.

So when this one is closed, in many cases you have to [inaudible 00:17:49], but otherwise you just be patient because there might be just an accident and then this will relieve traffic afterwards. But if there's something on the periphery [inaudible 00:17:59] or then it might sometimes be difficult, but then if you make the highway run smoothly, you will find that traffic is actually running smooth.

So going back to chiropractic output, are we now focus on bio-potentials in general? So there are different type of bio-potentials. [inaudible 00:18:21] we have the ECG, EG, EOG of [inaudible 00:18:25], but my main focus, is that beautiful piece of meat that we call muscles. It's very beautiful. If you make it a cross section of the muscle and you look at it, very nice. And that's why I focus on the muscle. I can then either relieve you from pain, measuring from the outside, or give you some injection. Then I will just press this small needle inside the muscles and then capture the signal from inside.

So what are the measurement techniques that we use for investigating the muscles? I'm here focusing on the thing that we use or I use, but then the list is not exhaustive. You can use other type of imagery. You can use MRI to look at the muscles. But then we focus mostly on the electrophysiology. Looking at surface electrode and then also intermuscular, which just means inside, and also trying to make sense of the metabolism by using near infrared spectroscopy to try to measure the amount of oxygen that is being consumed inside the muscles.

The detection of EMG is quite simple. I can't teach you this, you know this better, and then just the question is what then happen when you manipulate the spine, and then can we then make a sense of this manipulation at the level of the periphery.

So one is activation. You have the point activated, you have a single unit activating and then the impulse travels along the muscle fibers, that means there's a certain velocity of traveling. You can have another motor unit which is a bit faster that will propagate faster than the first one and then also have a third one. But if we look at it now from the outside of the skin, you can then place two electrodes on the surface of your skin. Then

if we look at the first model units that is activated here... So we have a certain distance between the skin and the source. In the same way, when we need more force, the second motor unit will fire, also at a certain distance from the skin and then the third one may also fire.

What we measure now from the surface is a kind of average input coming from different motor units. So with two electrode only, we can have an idea on the strengths and the amount of force that is being applied and how much the nerve is actually activating different fibers. From the inside the muscle, then, we can put some needle inside, especially if you go to the hospital, in most of the neurology department and we use needle because with needle it's easy if you miss someway you can just take it out, in again and then [inaudible 00:21:50]. But in my lab we prefer wires because very flexible wires... This is because we use a lot of functional movement and then with needles because they are stiff it can because pain. But if you have very flexible wire that will actually move with the contracting apparatus.

Then of course on the surface you will have something that is much more blurred. Where the first one you see single spike activated, in the last one is more blurred as a sum of different spike that are coming together onto the electrode. Let's see if we can work this one. So if we listen to... There is sound?

Audience: [inaudible 00:22:53].

Ernest K.: Oh nothing. That's it. Is running. It's not [inaudible 00:23:11]. So it's how the motor units sound when you capture [inaudible 00:23:15] it's really very loud. If I do the same with surface electrode you get nothing because actually taking low frequency content. And if in terms of amplitude you are working in the millivolt range with intramuscular because you are very close to the source while the surface you are working in a micro voltage range.

So those are the different type of needles we use. We basically use wires, so you feed the wire inside a normal needle, and then once in the muscle you pull the needle out, then the wires inside can then allow you to do measurement. There are different types that are being developed where you can have wires with different contacts, especially if you make a transversal insertion. Then you capture many more motor units that are being activated for an application.

So then, one way to do those investigations from the surface point of view is just to place two electrodes. One is active, another one is actually just zero potential, is placed on the bone or somewhere. And then what you do, you measure that potential difference between those two or you can use two electrodes or pair of electors and then you capture the difference between the potentials. Or we can also do much more where we place electrodes along the direction of the fibers and this allows us to have a multichannel EMG that allows us then to understand how to compute many more variables from the signal.

That means if we have a single channel, coming from two electrodes, we have a single activation, we can add two more. And then making sure that we have one which is really on both side of the enervation zones because the muscle inputs will travel both directions. And then you do difference, then it cancels out and if you take the next one, it gives you another view of the activation. And then what you can do, you can just keep on adding more electrodes and then giving you different signals. And when you have enough, what you get now is a more dense signal that actually start to give you a very nice propagation of the activities in the muscle. You can then use those signals to make interpretation on how fast the impulse is actually traveling on the muscles.

So different [inaudible 00:26:06] that you can use. We have metal [inaudible 00:26:08], more flexible ones, depending on the size of the muscle. Then you have different, then I got this slide from the company... Is that mine?

Audience: It's mine. [inaudible 00:26:19].

Ernest K.: Okay. In the same way we can also use high density EMG so we have a one single row or collum. Can we then make it multiples? If we [inaudible 00:26:31] we get the bipolar, we get what we can [inaudible 00:26:33]. We can then decide to cover the entire muscle with electrodes. That will give us a more dense way of capturing what is going on in the muscle. And then of course we also have what we call electrode matrices that then are of different size depending on the size of the muscle that you are targeting.

So how does it change? Simple relationship between muscle and force, if you just have your elbow in position, you have very small activities, you can start adding weight. While you add weight what you see typically the energy in the muscle is increasing in terms of amplitude, and then you can keep on increasing the weight until you really see large activities coming from the muscles where you try to recruit the entire muscle. The same way when you are fatigue. Then in many cases you can show that the activities will start to decrease because the large fibers that will fatigue soon will start to shut down and then you have the less dense amplitude in your signal.

In a same way, [inaudible 00:27:48] in a way or in matrix, you can then actually look at the propagation of your signal. And then knowing the time that is takes between the electrode or to travel the space, also knowing the space between different electrode, you can just make simple math computing distance divided by time, which gives you the velocity of propagation of your muscle.

If we take the role of muscle fatigue... If you ask someone to actually hold a contraction about 70% of MVC, at some point they can't take it anymore, they start to give up. If you look at now the manifestation of that time in the EMG, you might see also that the velocity of the EMG is actually decreasing because as we know large fibers will conduct faster and when they start to shut off, that means the average velocity of the conduction will actually decrease.

In the same way. If you look at the frequency domain, you see decrease in the frequency and many other parameters like amplitude and also different factor dimensions will

change because of some input, in this case fatigue. Using identity you can also make sense of the distribution of the activities around your muscles. So you can easily see which part of the muscles is being activated and when. One of the simple example is this... That's what we did in all the ones where we have the high level amputee. What was remark of this guy was that when he was imagining to close his hand or move the wrist, we see the chest muscle moving, without any TMR surgery.

So then what we did, we put just a bunch of electrode, that was the master study. And then you can easily see just from the map, when he's trying to do elbow extension, you have activities focusing on the first channels here. And then when he is trying to do elbow flection, you have a shift in the change in the activities and in my case that what we use to control the prothesis. And then you can actually make a sense of giving an amputee a much more natural control of the prosthetic.

But again good indication of activities but could be misleading because of the synchronization of motor units. As we know, we are actually just taking the average of whatever is coming here. If you have reversed polarity that means they might actually counseled each other. You may have a lot of activities but from the surface you are not measuring enough information.

And then we have a lot of data now. We are also able to do EMG decomposition so we can track back and identify the activities of each single motor unit. With intra muscular, we've been doing that for many years now, but limited in terms of how much force we can actually identify in terms of units. But with high density, we can now make identification of motor unit at much higher force level. There are now studies showing that even up to 70% MVC, you can still be able to recognize different activated motor units. And again, that's what allow us to look at the recruitment order, fiber type, discharge rate, so that we can actually make sense of understanding how many units are being activated, given a specific input.

So then how does those paterna change after chiropractic adjustment? Can we make... Now we have looked at the [inaudible 00:31:51] velocity, discharge rate, recruitment whatever we see after adjustment, can we then try to understand the process based on the variable that we're actually measuring from those high density system. Then we did a study looking at the effect of single physical chiropractic adjustment on the electrophysiology properties of [inaudible 00:32:16] into your muscle using high density EMG. It is now not a secret anymore that useful chiropractic being sure to be useful now for many conditions. And the same time a number of studies have shown an increase in muscle strength following chiropractic care. So it's not by chance anymore because the evidence is being now build up and then can we then try to quantify those neuro physical changes based on the output which is the EMG.

That was the main focus of the study, looking at the variables of the EMG and trying to explain why we see this increase in muscle strength. Three was actually the easy, we have someone sitting nicely on the chair and then you have a force pedal measuring are much force they're actually doing during dorsiflexion. We have the matrix of electrode covering the tibialis anterior and then we have the needle inside as well to measure

from inside the body. We have a very [inaudible 00:33:28] here and then with the high density you see they have a 64 different channels behaving at... And then the subject will ask to do some movement and then we will then try to understand pre and post adjustment, how does it change?

This is just a view of one leg, where we placed electrodes, before we connect any wire and this is where things get messy, where you have the wire, you have the matrix here, you have the wire insertion here. And then force pedal where the subject is actually sitting nicely on a lazy chair. So it's [inaudible 00:34:14] here we had actually 12 participants, I was one, 12 participant then in the randomized controlled crossover design where we have a false doctor in line doing the adjustment for the control. Sorry?

Audience: [inaudible 00:34:28] the adjustments?

Ernest K.: They are an intervention. And then we have a control group as well.

Yeah, so then the exam was taking maximum motor contraction three times, and then looking at the highest number in terms of how much maximum force they can actual apply. And then we do some pre-recording before adjustment and post recording. And the adjustment was either passive movement or a proper chiropractic with a week or at least seven days washout period. And at the end we will again measure the maximum motor contraction to see if there's any change just after the intervention.

So then we look at the [inaudible 00:35:21], how can we then see if the muscles is conducting impulses much faster. That what we saw and again based on the multiple channels you can look at the contraction velocity. We also did the composition based on intra muscular EMG where we identify different unit and then try to look if their discharge rate is changing after intervention.

So before I talked to the result, we did now a similar study but then using a metabolic approach and then we use near infrared spectroscopy to try to measure the quantity of oxygen being consumed in the body. So we all know about pulse oximetry that we probably have tried in hospital. The basic principle is that you have light, you send light at different wavelength and then you have detectors. What's happening is that inside the blood, the hemoglobin that oxygenated will absorb the light in one way and the non oxygenated will also absorb light in a different way. And then you can make sense of those difference here and then compute the ratio to know what is the percentage of hemoglobin that is actually oxygenated in the blood.

This is one way that we use most in the hospital. The other way is if you place both the optode and then the decoder on one side, that's what we use in the muscles. Because we can't really go through the entire limb, so we try to make sense of recording the refraction of the light and then try to calculate how much oxygen is actually being consumed. You can look at the blood flow, you can look at consumption or the recover, especially for studies where you do an arterial occlusion, we can clearly see that during the occlusion you consume a lot of oxygen, so the concentration of hemoglobin with

oxygen is decreasing and then after you release you have the overshoot and then the system stabilize itself.

Can we then do the same with much less? In this case here, you can also put a lot of optode and then getting almost a similar image as we did for high density. Looking at the distribution of muscle oxygen consumption inside the muscle.

For today, now we'll just use a [inaudible 00:37:57] with 13 participants. This study was run in Oakland, the first one was in Aalborg and then this case with the 30% MVC just to allow a bit of local ischemia in the muscle and allowing oxygen to be consumed properly. And I was lucky to be adjusted by two professionals and actually that the first time I start to believe that it's working because I do have compartment syndrome. And then after that adjustment I went back to my hotel the next morning I took a run. I still had pain, but pain was actually delayed compared to my normal running. So it's doing something, but what it's doing then it's up to us to find out.

For both studies we found a significant increase in ankle dorsiflexion and [inaudible 00:38:48] so the force is increased, that means motor control was altered. This confirms previous studies. And then potential causes are many. It could be faster recruitment, improve recruitment of larger fibers or maybe change the properties but the diameters of the fibers is unlikely because we can't just modify the diameters after one session. But what we saw is that the velocity of conduction increased by almost 20% in the population after chiropractic adjustment. But we found no significant change in the discharge rate based on intramuscular EMG, probably because we are recruiting at 10%. At 10% we assume mainly small fibers are active and probably the effect is mostly on large fibers than on small fibers.

Again also for [inaudible 00:39:49] we found no significant change in the consumption of oxygen after both pre and post distance for the intervention group. This is for the control group but we see a tendency of lower consumption in the intervention group because if the maximum voluntary contraction is increase, that means that 10% that we are taking based on the pre-MVC is not 10% anymore. So the body is actually... To provide the same amount of force, the body's using less effort and we believe probably if we go a bit higher in terms of MVC, we might see a larger effect on oxygen consumption. So far, no change, no difference was between pre and post in both groups using metabolic measurement.

The next step now is to look at more [inaudible 00:40:56] that we have. Can we then increase... If we have an idea that they're actually, as I'm assuming, that after adjustment we actually provide a body a certain optimum way of activating the fibers. It could be that before the adjustment, I do MVC, but I don't really recruit all the fibers, but maybe after adjustment the body then get a more optimal way, probably decrease threshold of excitation and then getting those [inaudible 00:41:29] in fibers being recruited and increasing the thing. Thank you for listing. And then I thank my collaborators.