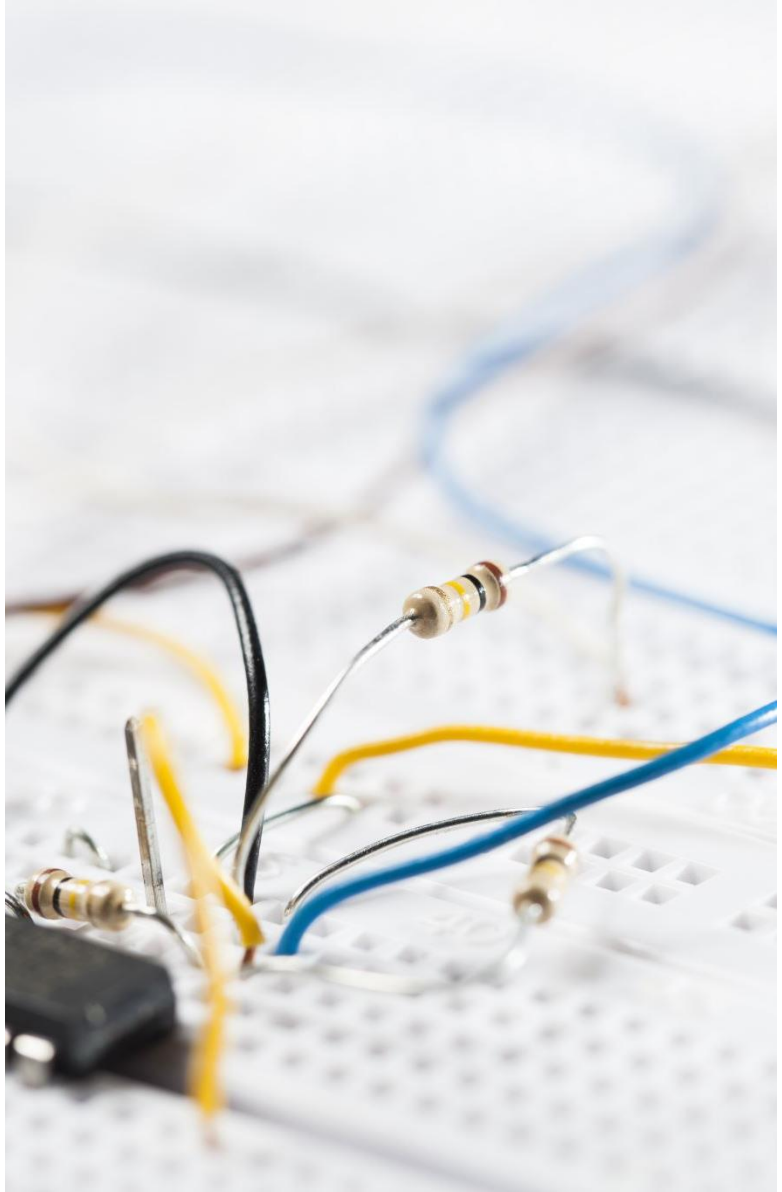

BIOELECTRICAL IMPEDANCE TECHNOLOGY

Our Team

Danial Khan

Melika Joulaei

Rohan Patel

Shachi Desai

Ines Qian

Srinidhi Shankar

Disclaimer

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PRESENTATION ROADMAP

Main Claim:

Our bioelectric impedance method for sensing hydration provides a solution to the inaccurate and non-invasive/non-portable hydration sensors currently on the market.

Rohan Patel

PRESENTATION ROADMAP

Project Background…………………………………………… ....Rohan Patel

Objectives…………………………………………………… ....Srinidhi Shankar

Overview of Alternative Designs………………………………. ....Srinidhi Shankar

Sub-claim #1: Our proposed design focuses on improvements in accuracy……….Shachi Desai

Sub-claim #2: Our device will have medical-grade accuracy…………………………Melika Joulaei,
………………………………………………………………. ………Ines Qian

Sub-claim #3: The devices portability will allow for integration into a smart watch. ..Danial Khan,
…………………………………………………………………......……..Rohan Patel

Conclusion …………………………………………………… ....Rohan Patel

Rohan Patel

PROJECT BACKGROUND

88% of athletes face hypohydration during exercise [1]

[2]

However, current non-invasive body hydration sensors are inaccurate

Srinidhi Shankar

IMPORTANT PRIORITIES

This design must be / have:

- Non-invasive
- Accurate to +/- 5%
- Under a mass of 30 grams
- A lifespan of three years

Benchmark for accuracy – Electrolyte Analysis [3]

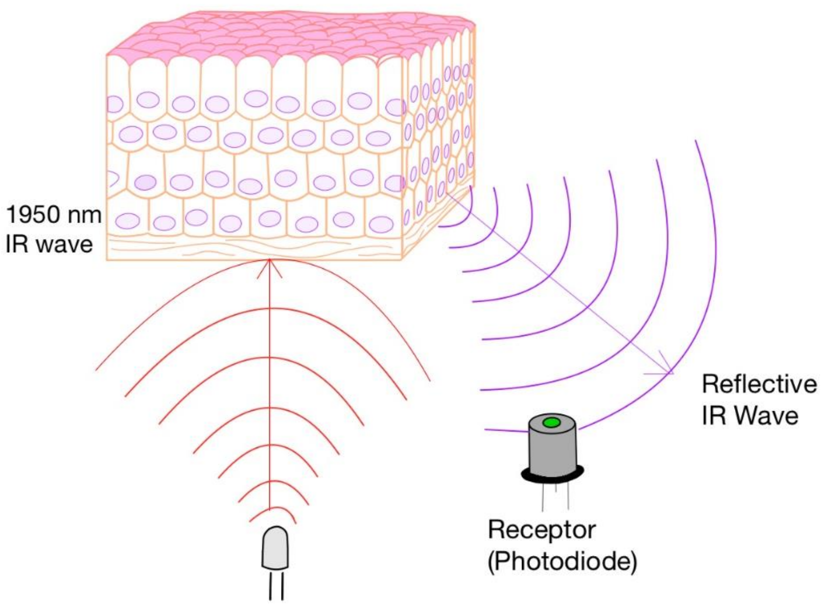
Benchmark for mass - Apple Watch [4]

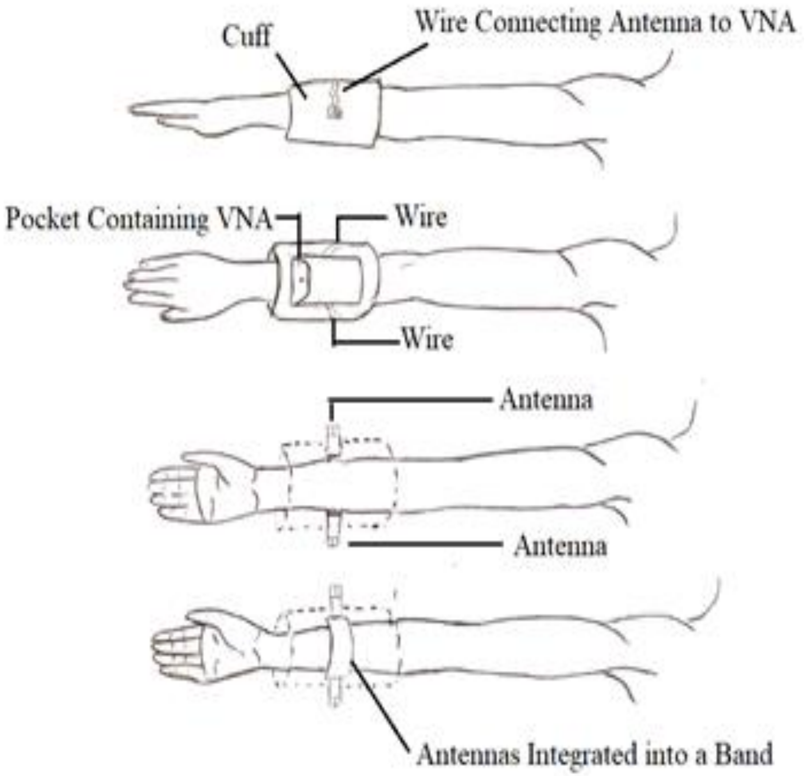
ALTERNATIVE DESIGNS

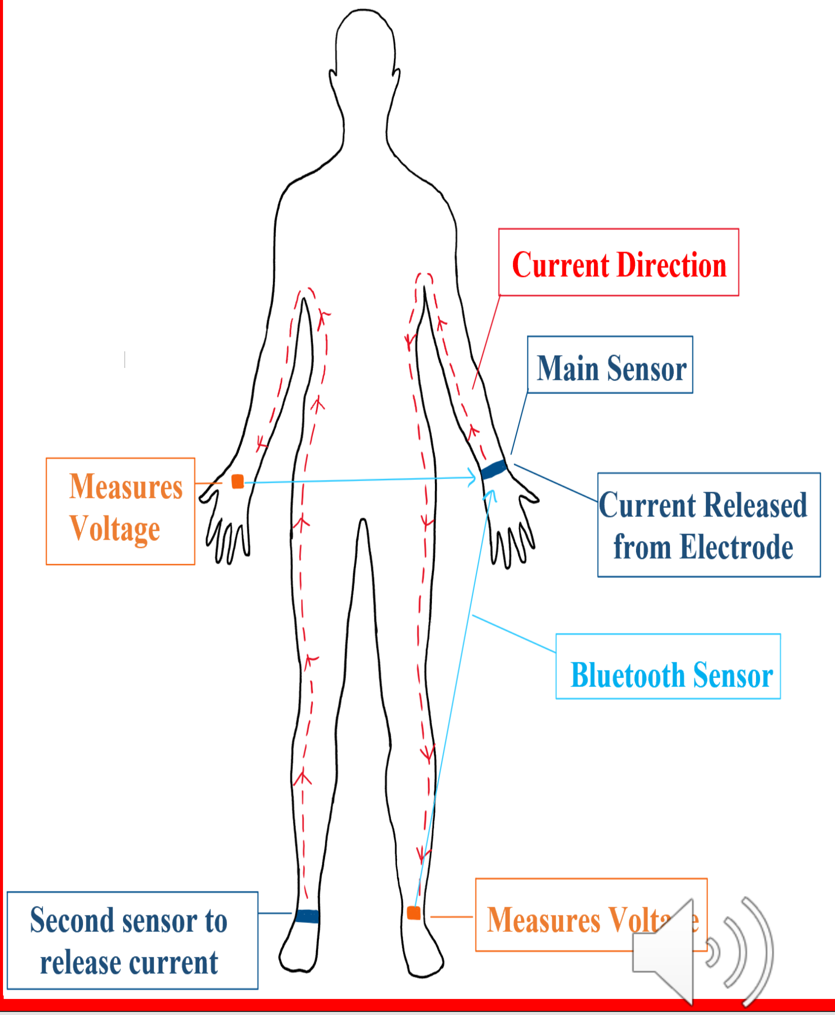
Srinidhi Shankar

3 SOLUTION IDEAS

Infrared Laser Spectroscopy	Microwave Technology	Bioelectric Impedance





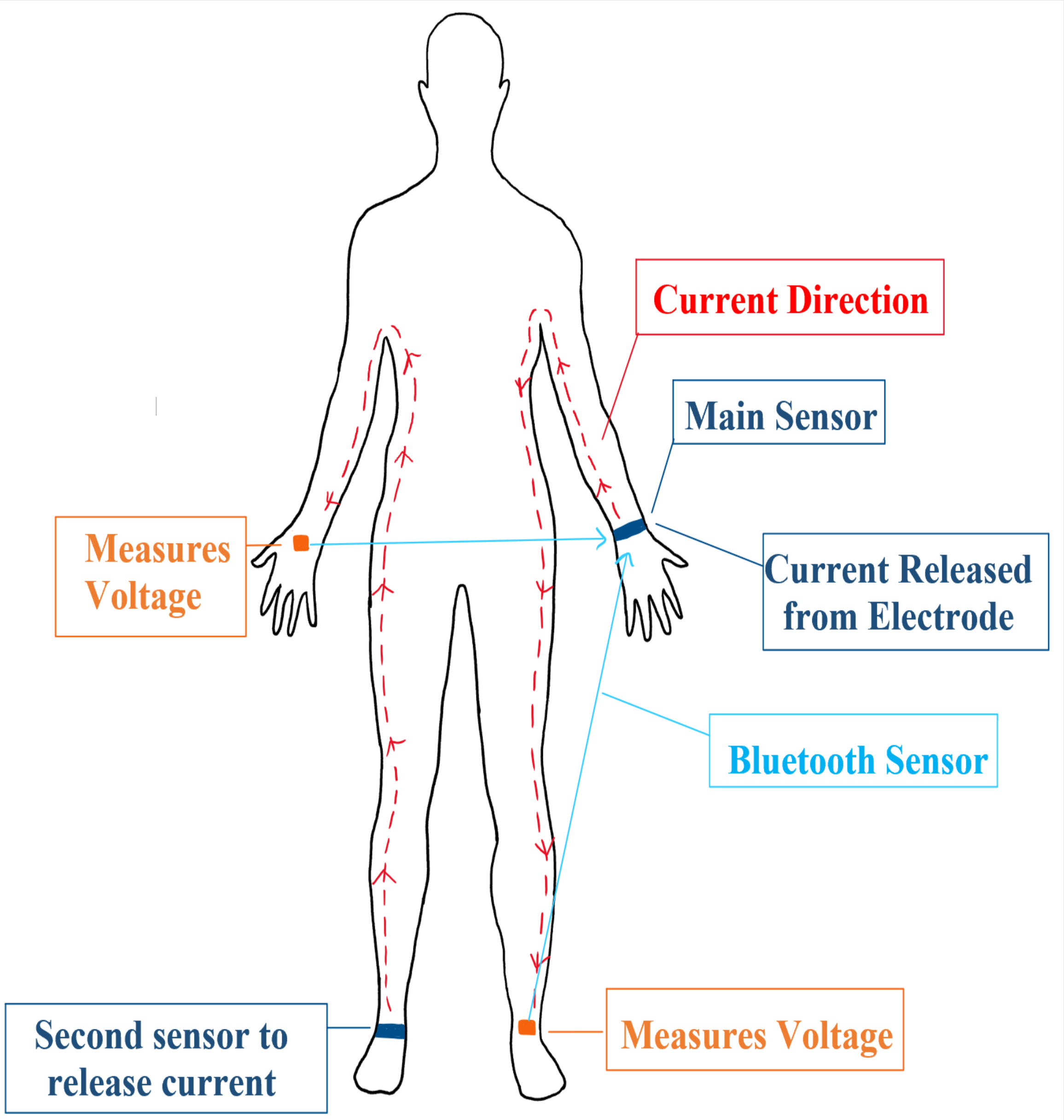


SUBCLAIM 1: WE HAVE A PROPOSED BIOELECTRIC DESIGN THAT FOCUSES ON IMPROVEMENTS IN ACCURACY.

Shachi Desai

WHY DID WE CHOOSE THE BIO-ELECTRICAL DESIGN?

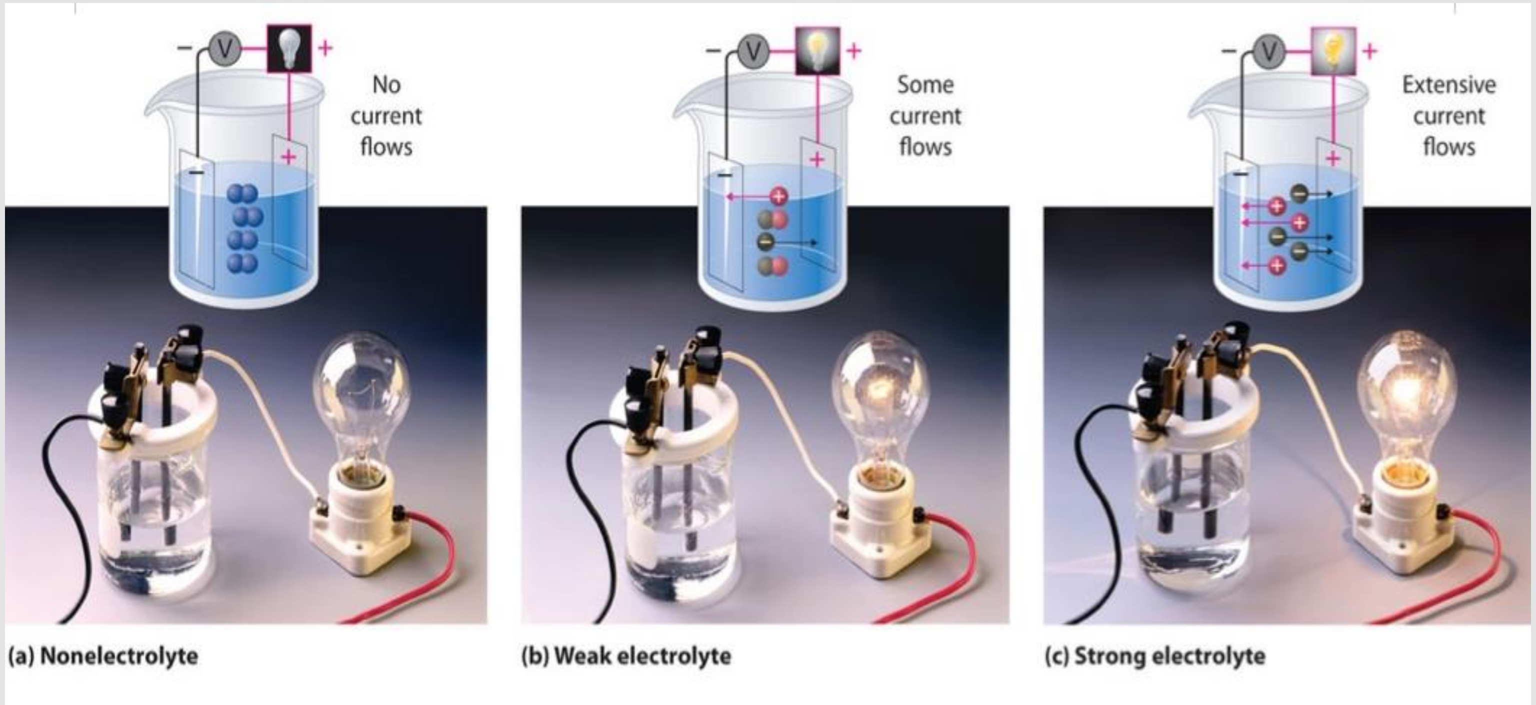
- A current will be passed through body tissues using a bioprocessing chip
- The device has two sensors, one on each side for increased accuracy



Shachi Desai

WHY DO WE HAVE TWO SENSORS?

- Research says the 8-electrode method is more accurate than the four-electrode method [5]



[6]

Shachi Desai

IMPROVEMENTS TO EXISTING BIOELECTRIC IMPEDANCE TECHNOLOGY

Current Solution	Our Solution
Manually choose when the current passes	Programmed to send a current at 10 second intervals
Not portable	Similar to a wrist watch and portable

[7]

Ines Qian

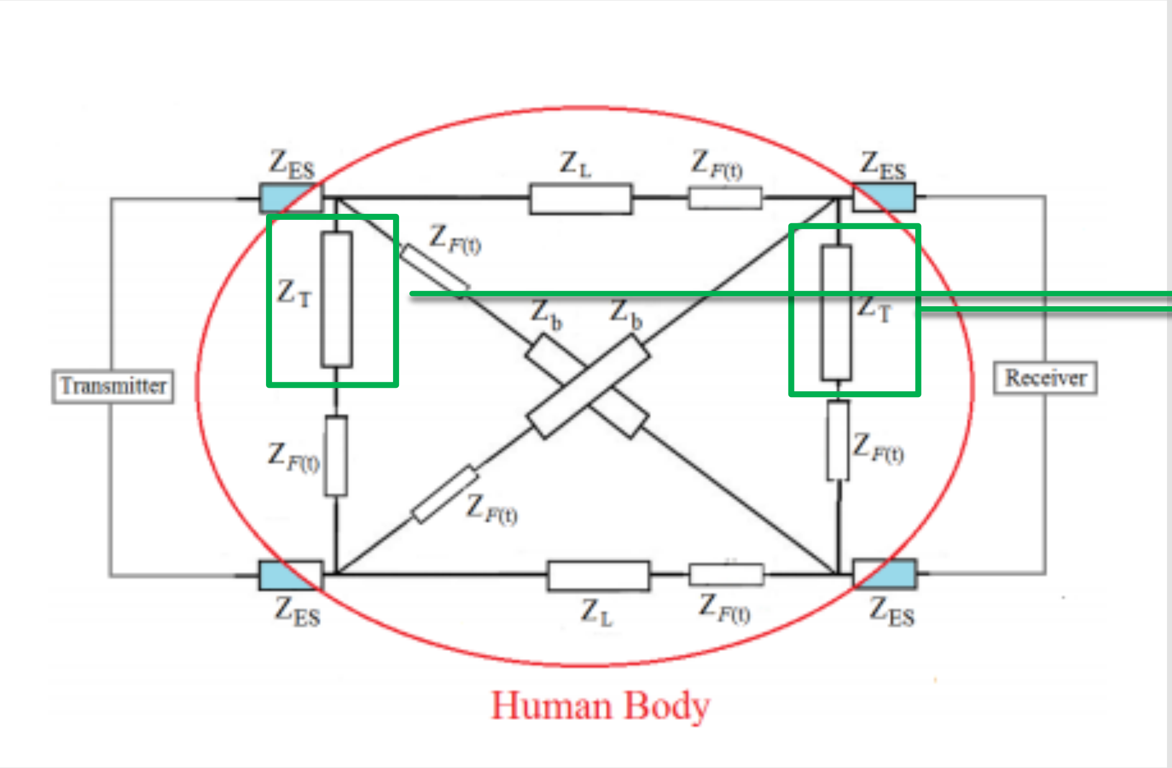
SUBCLAIM 2: OUR DEVICE WILL HAVE MEDICAL-GRADE ACCURACY

The team has detailed plans for measurement of the proposed design's success in sensitivity and accuracy, so the team can ensure that the design will be accurate for all possible user groups and can be implemented.

Ines Qian

IN-SILICO [8] TESTING: VALID SIMULATION TO TEST SENSITIVITY

- Circuit Simulation for Body Impedance [9]



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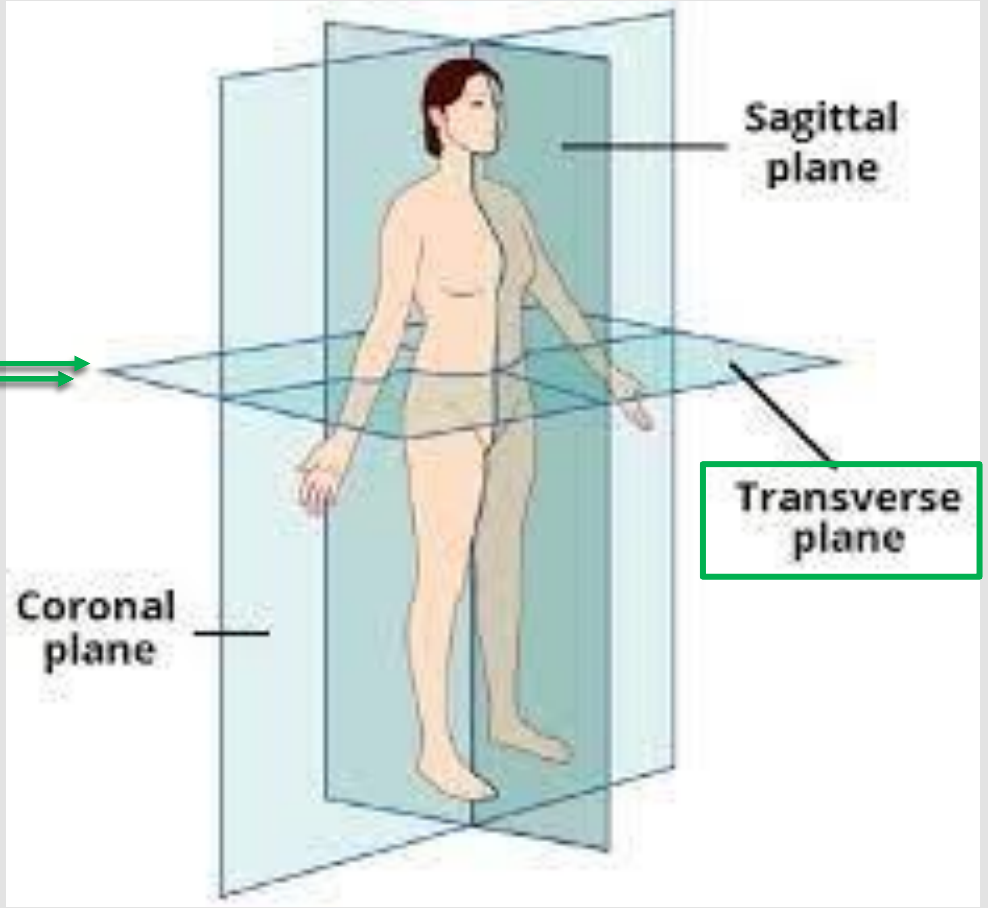

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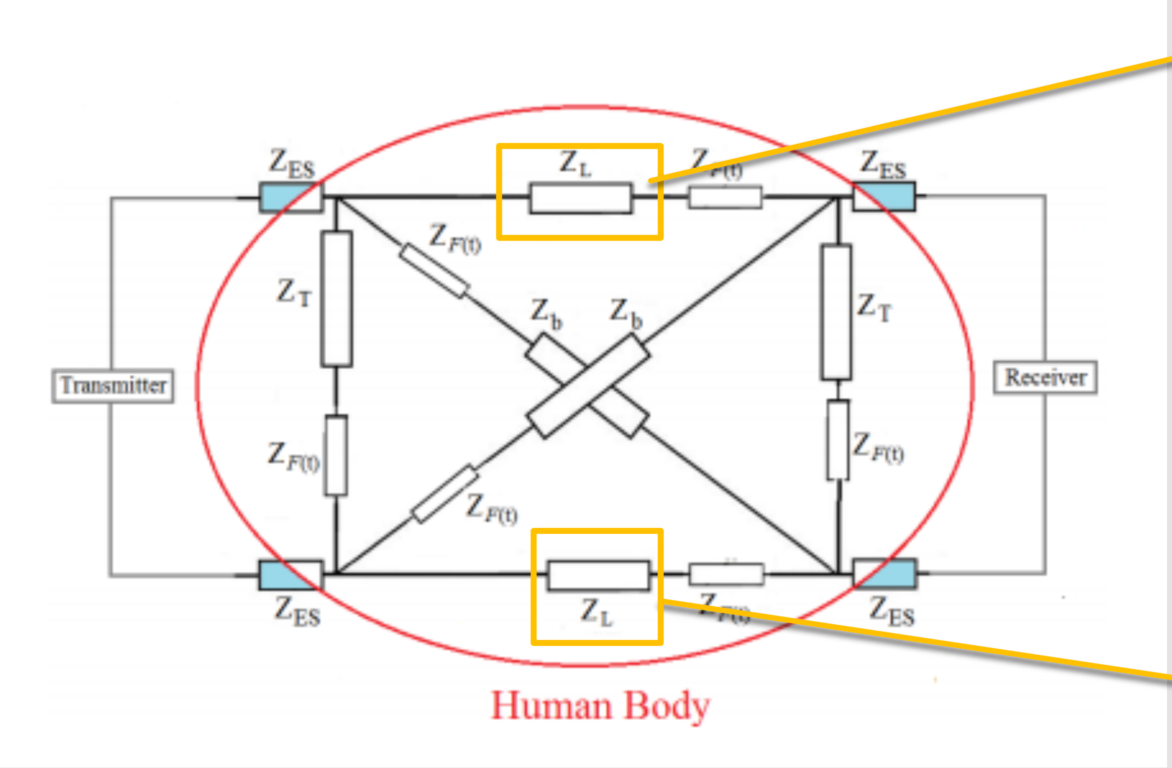
IN-SILICO [8] TESTING: VALID SIMULATION TO TEST SENSITIVITY

- Circuit Simulation for Body Impedance [9]



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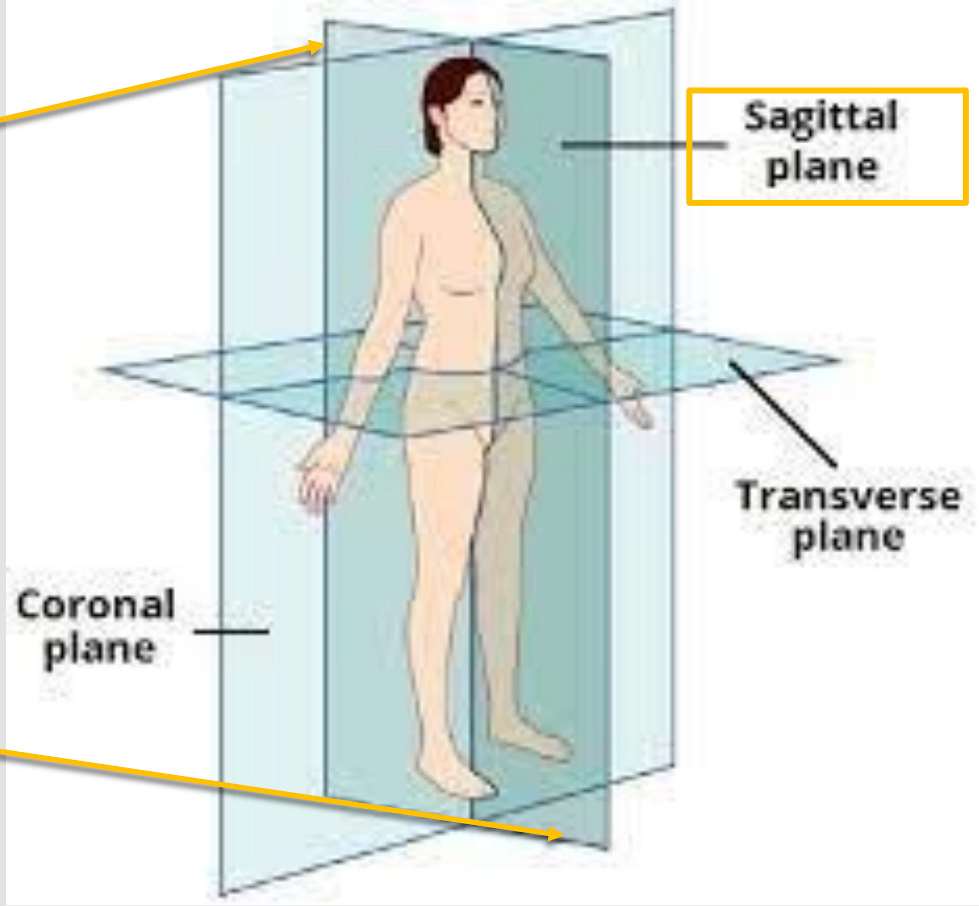
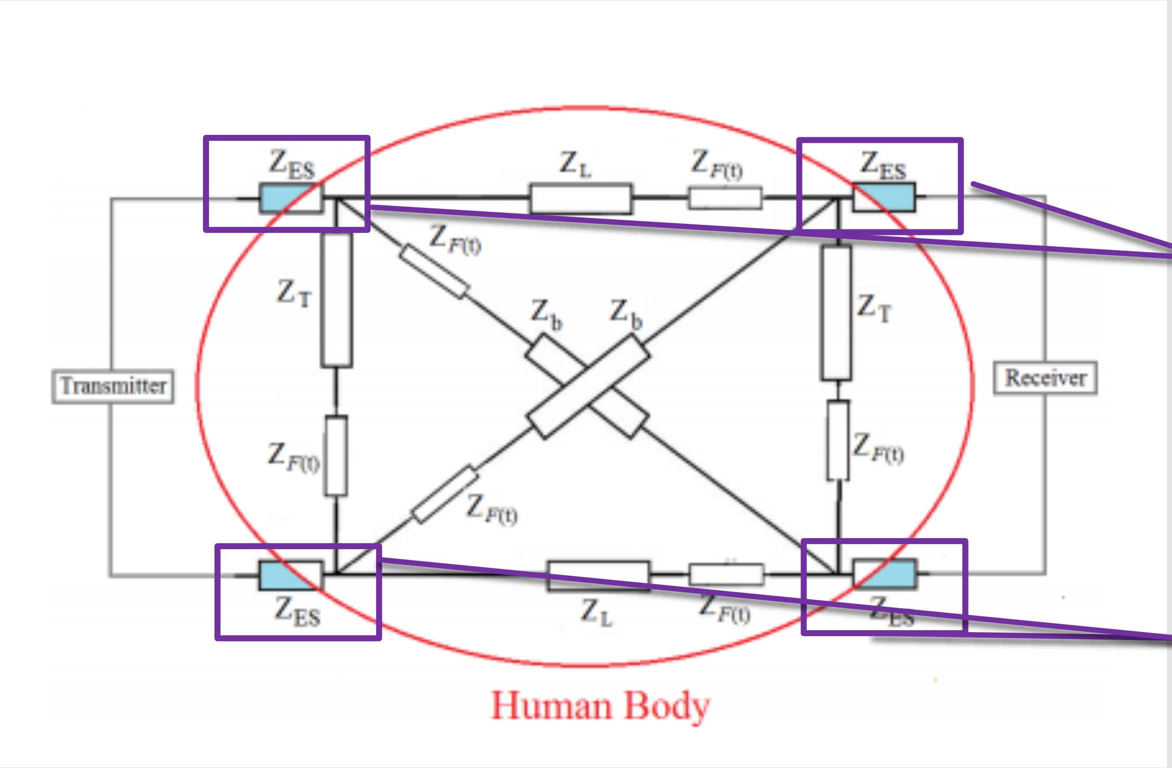


[11]

Ines Qian

IN-SILICO [8] TESTING: VALID SIMULATION TO TEST SENSITIVITY

- Circuit Simulation for Body Impedance [9]



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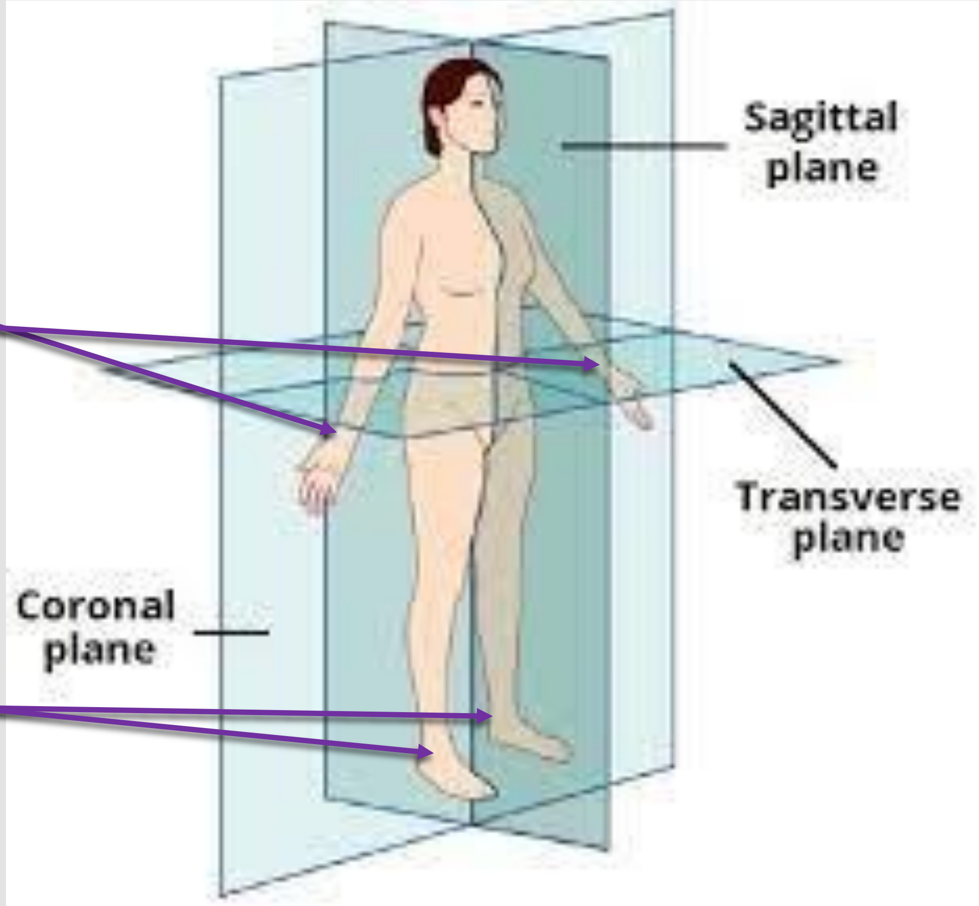

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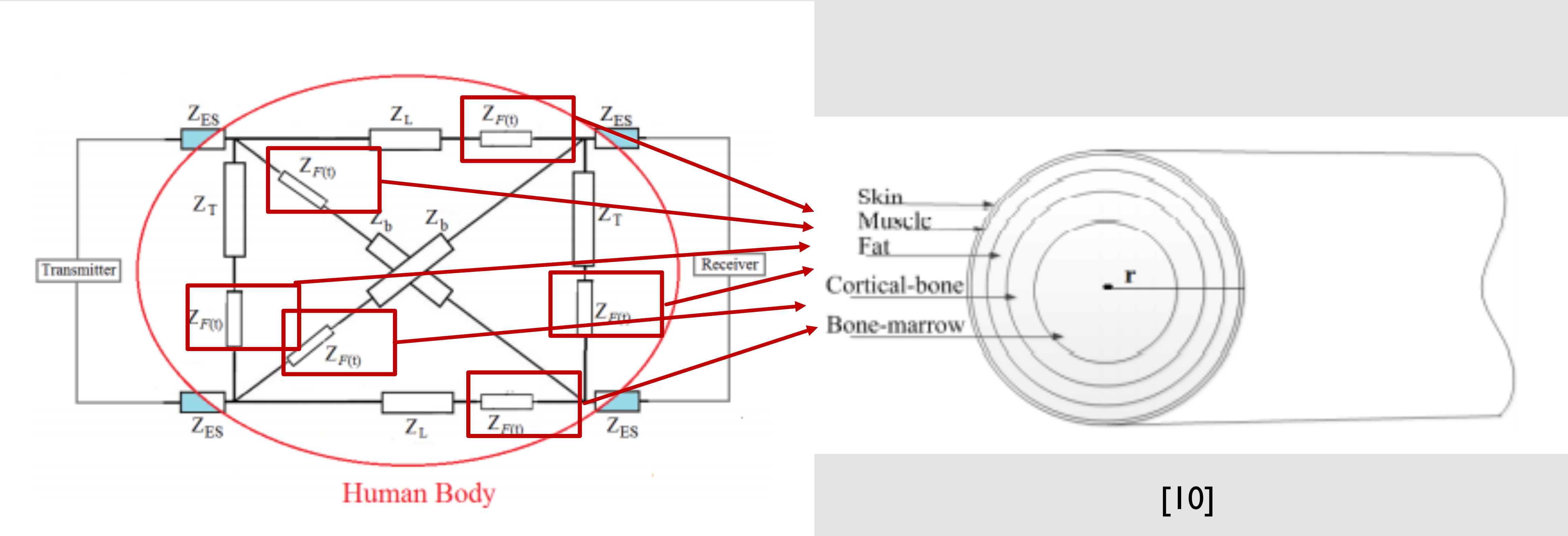

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Ines Qian

IN-SILICO [8] TESTING: VALID SIMULATION TO TEST SENSITIVITY

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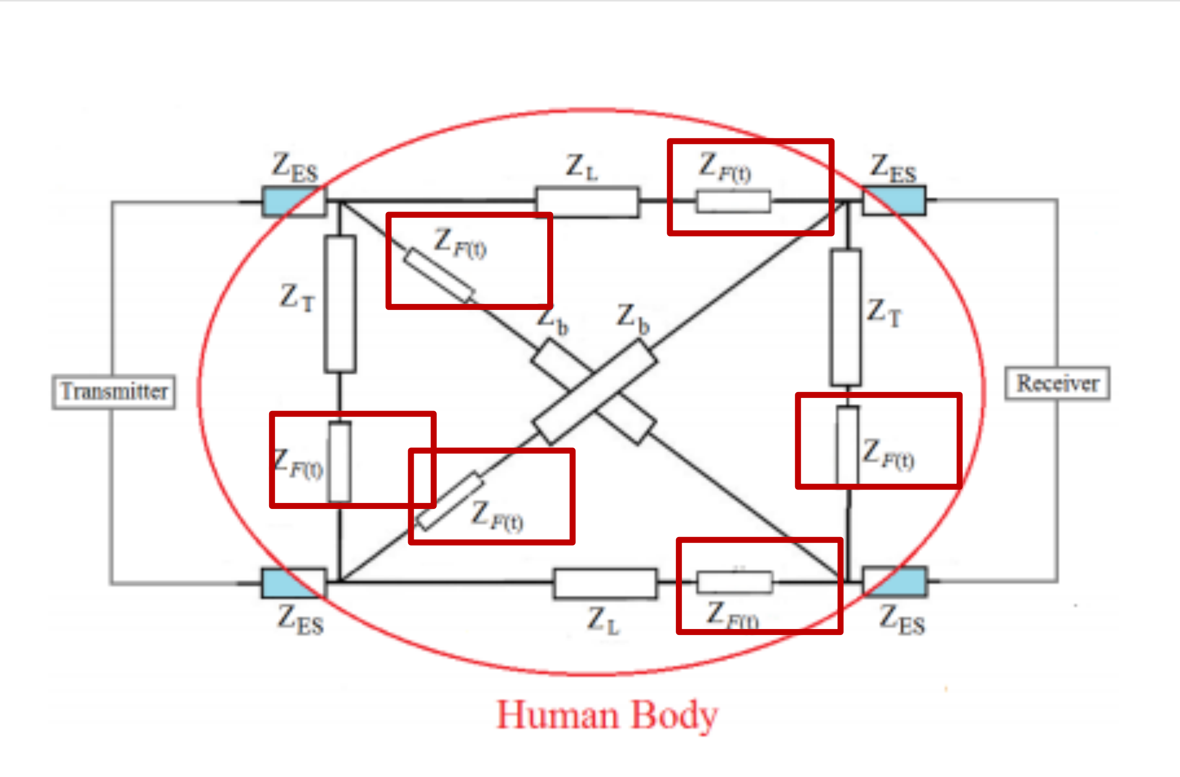


[10]

$$Z_F(t) = Z_{f0} - Z_w(1 - e^{-\frac{t}{\tau}})$$

[10]

Z_{f0}- "The impedance at time t=0 just before hydration begins." [10]

Z_w - "The impedance resulting from water consumed." [10]

$\frac{t}{\tau}$ - "A characteristic that predicts the rate of hydration." [10]

τ – "The time constant that characterises a particular individual." [10]

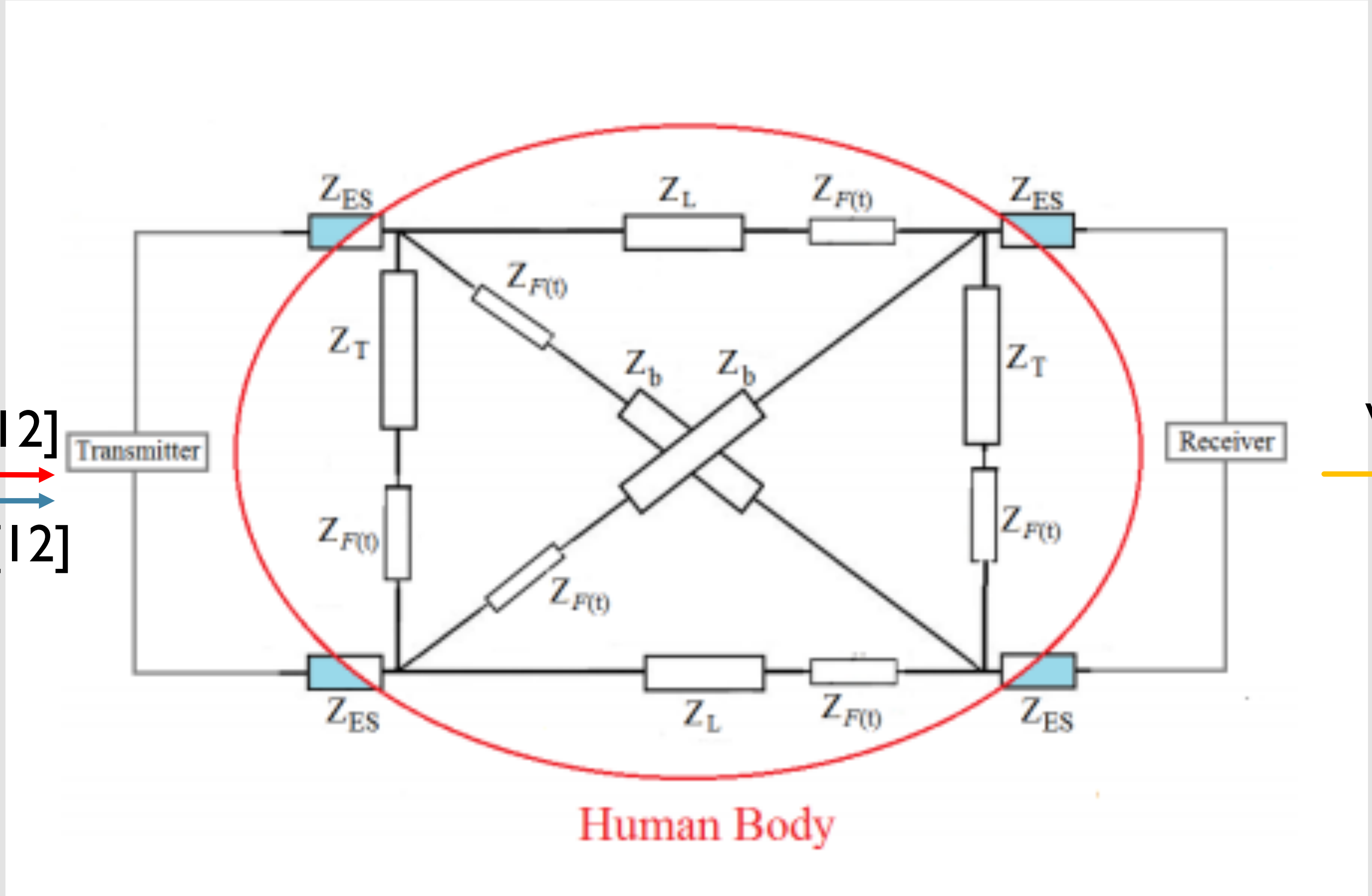
Ines Qian

IN-SILICO [8] TESTING: SENSITIVITY TEST

- Procedure

3.7V [12]

60mA [12]



[10]

Vf

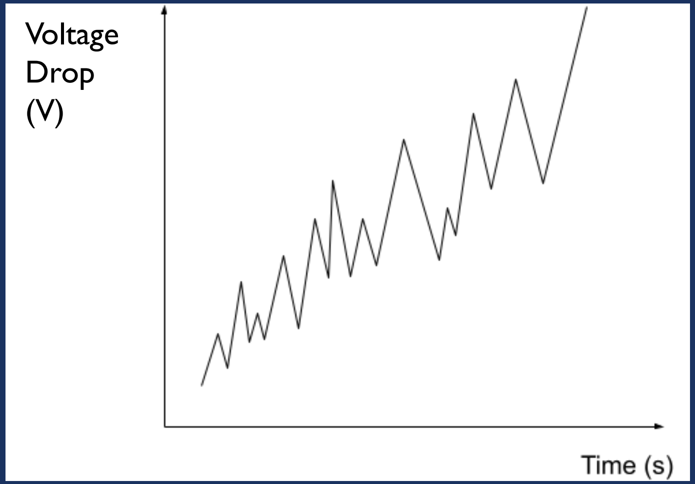
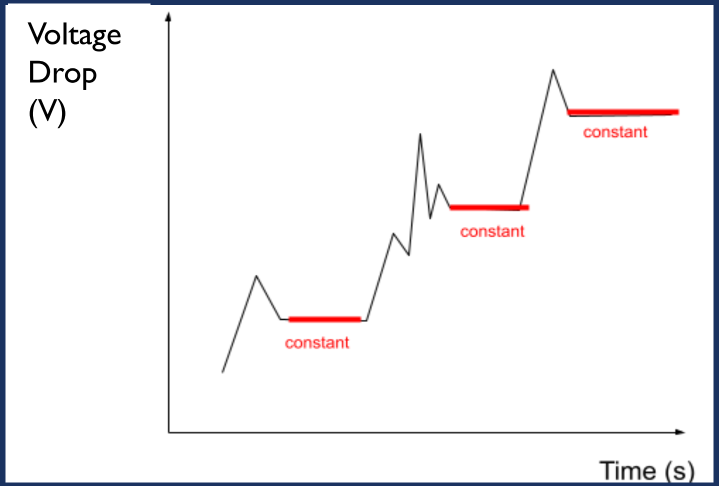
Voltage Drop= Vf-3.7V [12]

A higher hydration level will result in a lower impedance, which will decrease the voltage drop! [10]

Ines Qian

IN-SILICO [8] TESTING: POSSIBLE CONCLUSIONS FROM DATA ANALYSIS

- Plot the measuring result as a Voltage Drop vs. Time graph
- Potential result:

	
A continuously changing graph means that the device is sensitive to minor hydration level changes.	A graph with a lot of constant values and horizontal lines means that the sensitivity of the device is not ideal.

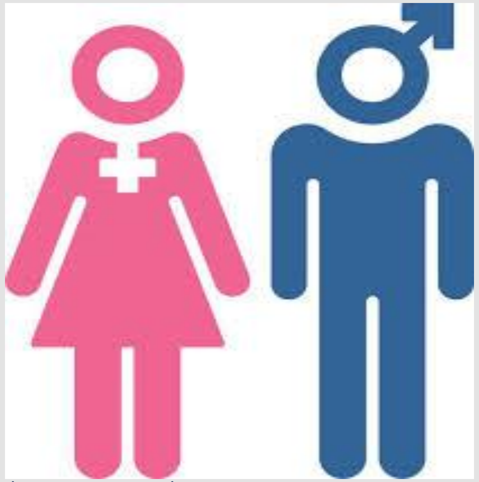
Melika Joulaei

CLINICAL TESTING: UNIVERSAL SAMPLE FOR TESTING

- Select sample of 54 individuals

- Include 3 males and 3 females from nine age groups

(10-20) (21-30) (31-40) (41-50) (51-60) (61-70) (71-80) (81-90) (91-100)



3*9=27 3*9=27

[13]

- Avoid individuals with diseases, conditions, or habits that affect their metabolic rate [14]

Melika Joulaei

CLINICAL TESTING: ACCURACY TEST PROCEDURE

Implement the device undertesting

- Place the four electrodes at the posterior sides of the samples' wrists and ankles.

Introduce changes

- Give each sample the same volume of water with the same electrolyte and mineral level.

Measure

- Turn on the prototypes to start measurements.
- Samples will be asked to stay in supine position to allow the muscle to relax. [15]

Melika Joulaei

CLINICAL TESTING: ACCURACY TEST PROCEDURE

Convert the resistance data collected to hydration level [13]

$$\mathrm{TBW}\ (\mathrm{kg}) = 1.84 + 0.45\left(\frac{\mathrm{height}^2\mathrm{square}}{\mathrm{resistance}}\right) + 0.11\,(\mathrm{weight}).$$

TBW represents total body water [16]

Use accurate hydration level measuring technique

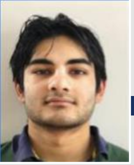
- Take blood samples

[17]

Compare results and measure percentage error and accuracy.

$$\text{Relative Error} = \frac{|\,measured - real\,|}{real}$$

SUBCLAIM 3: THE DEVICES PORTABILITY WILL ALLOW FOR INTEGRATION WITH A SMART WATCH.



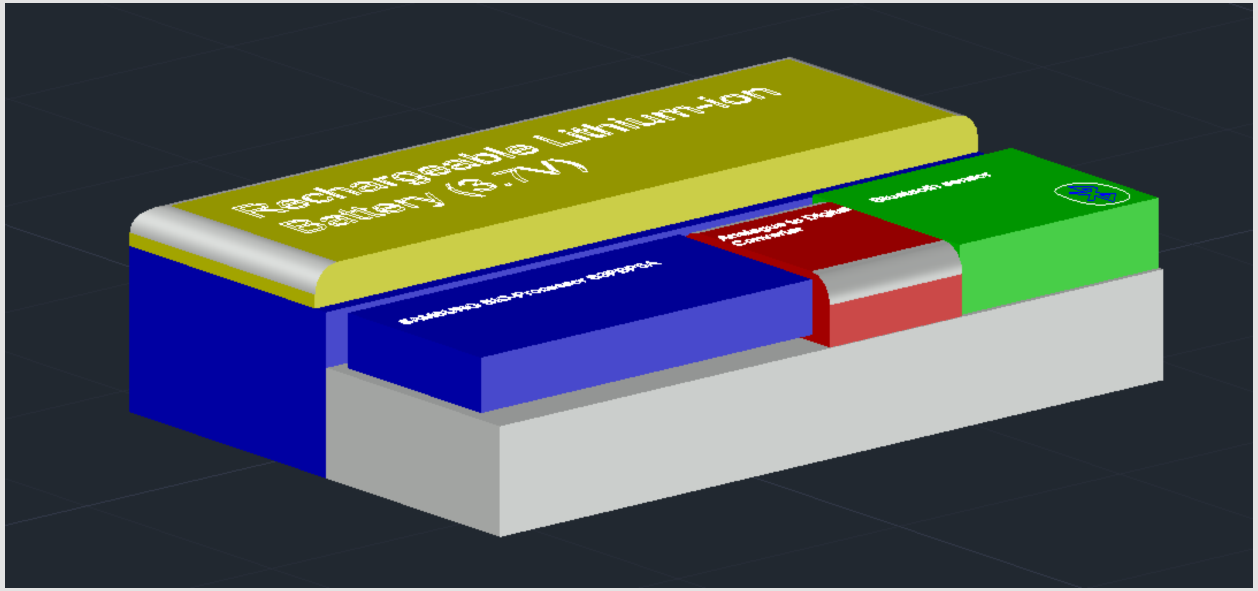
Danial Khan

PORTABILITY

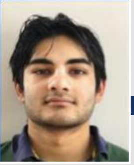
- Prioritized objective → need a non-invasive design having a mass of under 30g
  - Therefore, essential measure of success

Table 2: List of parts with associated masses

Part	Mass (g)
Bluetooth module	10 [18]
Samsung Bio-processor	6 [19]
Analogue to Digital convertor	3 [20]
3.7V Lithium Ion battery	10.5 [21]
TOTAL	29.5



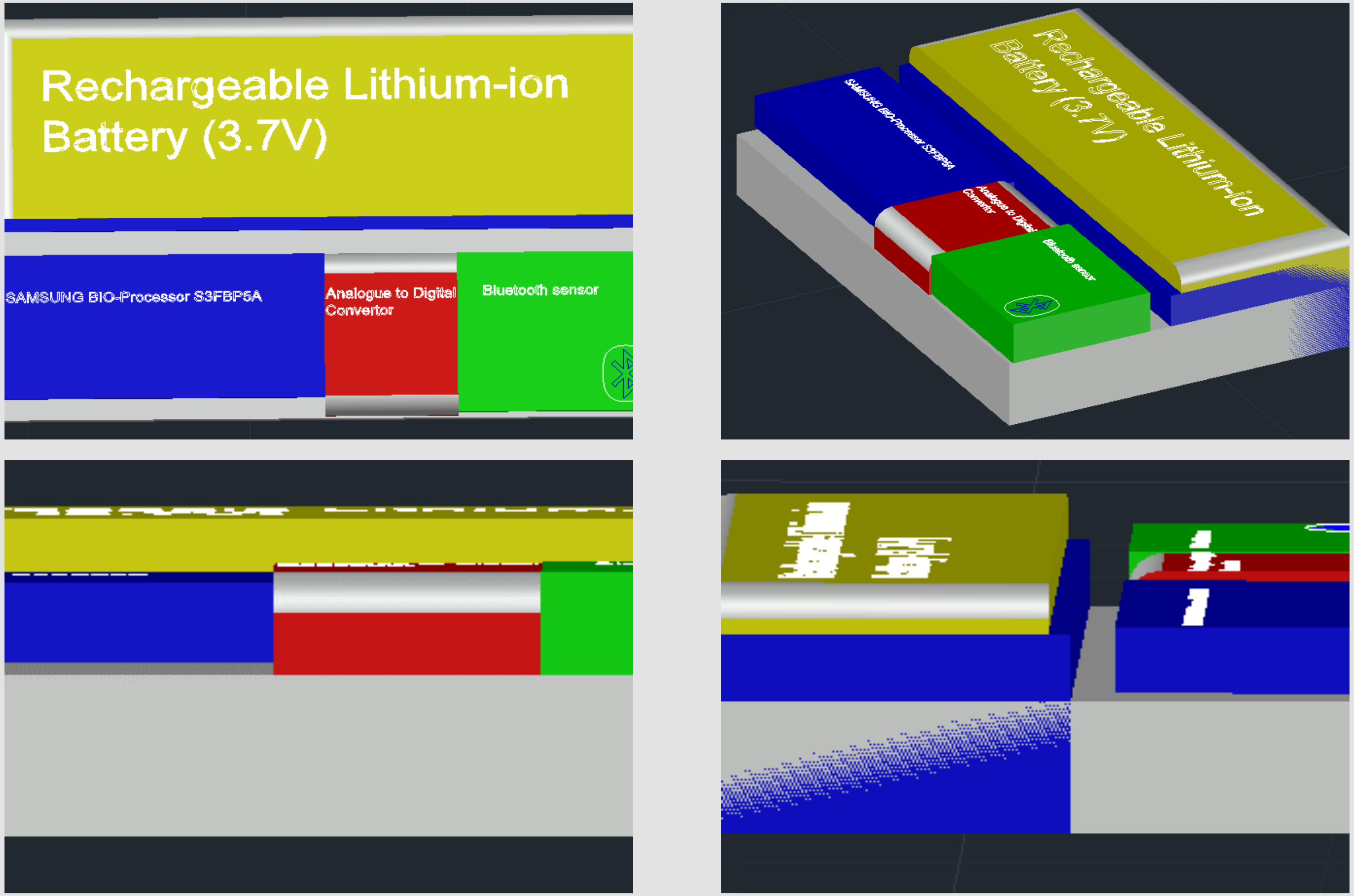
Angle #1 for AUTOCAD model



Danial Khan

ADDITIONAL AUTOCAD ANGLES

- 80% recyclable
- Total Mass → 29.5g [18][19][20][21]
- Maximum Dimensions → (30 x 20 x 8)mm

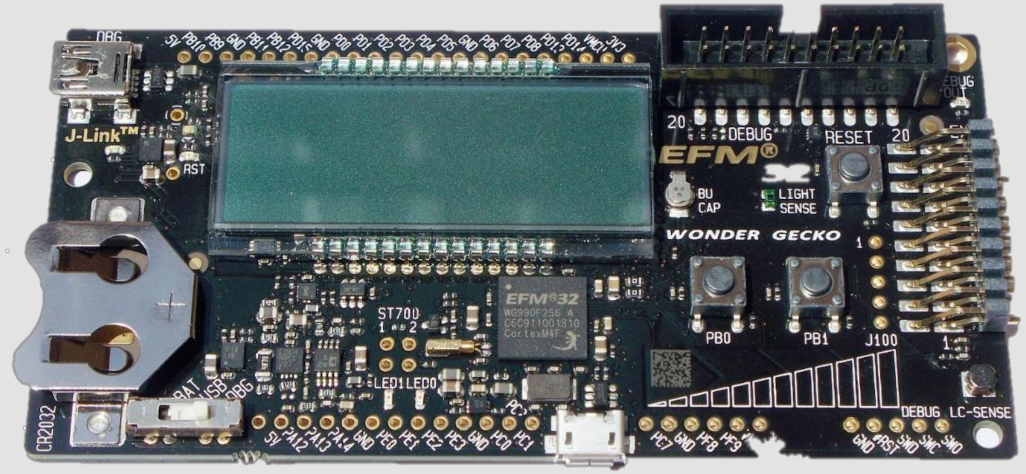


Additional AUTOCAD snapshots

Rohan Patel

POWER CONSUMPTION & BATTERY LIFE

- Power consumption: $32.82\ \frac{uW}{MHz}$ [22]
- Frequency: $10^5\ Hz$ [23]
- Device operates for 72 hours per charge



[22]

$$32.82\frac{uW}{\cancel{MHz}}\cdot 0.1\ \cancel{MHz}\cdot 72\ hours = \mathbf{0.0001183\ Wh}\ [Watt\cdot hours]$$

- Single Charge Battery life of Apple Watch: 1.13 Wh [24]

$$\frac{0.0001183\ Wh}{1.13\ Wh}\cdot 100\% = \mathbf{0.01\%}$$

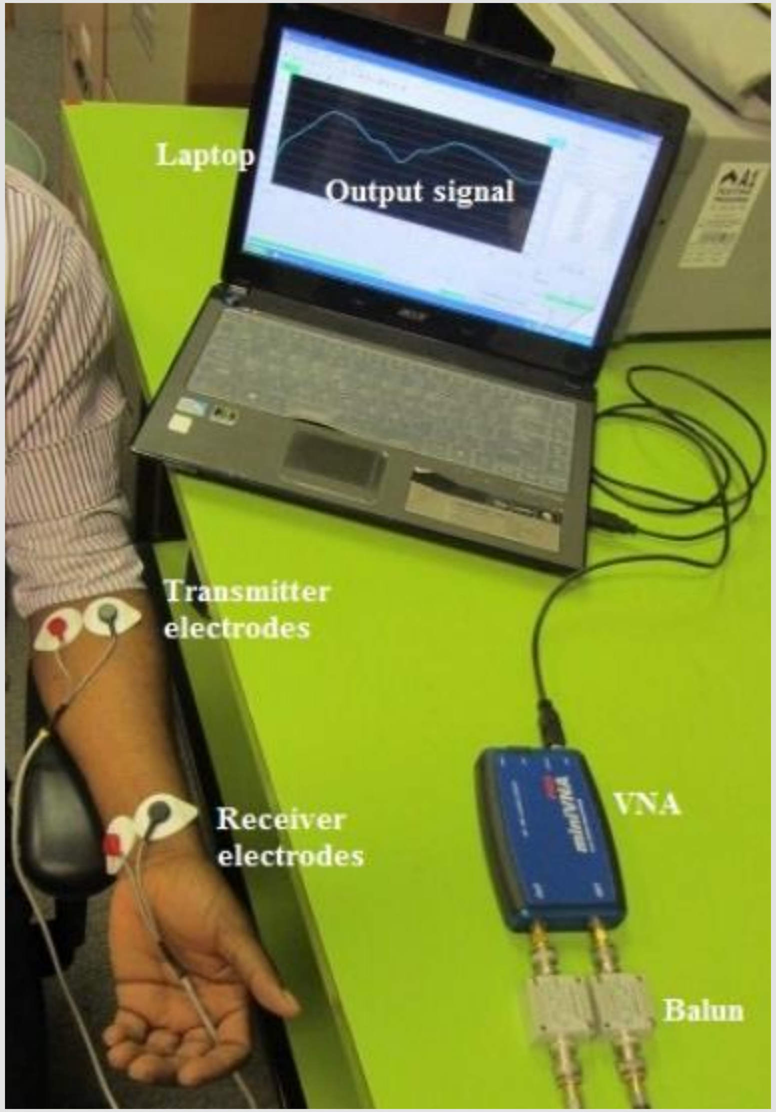
Rohan Patel

CONCLUSION AND NEXT STEPS

Device is accurate and portable

Test simulation to gauge sensitivity

Test prototype sensor to gauge accuracy



[10]

REFERENCES

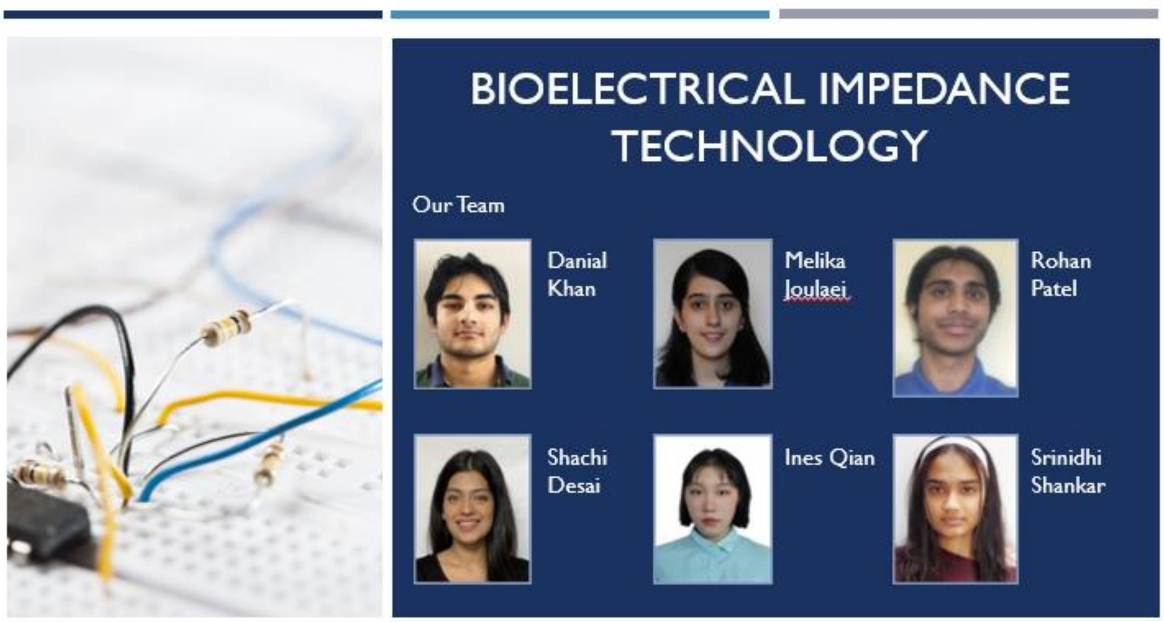
[1]R. P. Nuccio, K. A. Barnes, J. M. Carter, and L. B. Baker, “Fluid Balance in Team Sport Athletes and the Effect of Hypohydration on Cognitive, Technical, and Physical Performance,” *Sports medicine (Auckland, N.Z.)*, Oct-2017. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5603646/. [Accessed: 25-Apr-2021].
[2] “Guide to Staying Hydrated While Training: 5 Tips for Preventing Dehydration – Legend Fitness,” *Guide to Staying Hydrated While Training: 5 Tips for Preventing Dehydration*, 19-Oct-2018. [Online]. Available: https://www.legendfitness.com/2016/08/guide-to-staying-hydrated-while-training-5-tips-for-preventing-dehydration/. [Accessed: 18-Apr-2021].
[3] T. Kinman, "Sweat Electrolytes Test," 14 September 2018. [Online]. Available: https://www.healthline.com/health/sweat-electrolytes-test. [Accessed 24 April 2021].
[4] "Apple Watch Space Grey Aluminium Case with Black Sport Band," [Online]. Available: https://www.apple.com/ca/shop/buy-watch/apple-watch-series-3/38mm-gps-space-grey-aluminium black-sport-band. [Accessed 24 April 2021].
[5] Ming-fang Cheng, yu yawn Chen, Tsong-Rong Jang, Wen-Lang Lin, "Total body composition estimated by standing-posture 8-electrode bioelectrical impedance analysis in male wrestlers," ResearchGate, August 2016. [Online]. Available: https://www.researchgate.net/publication/309956610_Total_body_composition_estimated_by_standing-posture_8-electrode_bioelectrical_impedance_analysis_in_male_wrestlers. [Accessed April 2021].
[6]“Conductivity of Electrolytes Demonstration,” *Chemdemos*, 2012. [Online]. Available: https://chemdemos.uoregon.edu/demos/Conductivity-of-Electrolytes-Demonstration. [Accessed: 17-Apr-2021].
[7]L. Charder Electronic Co, “Body Composition,” *Height and Weight Scale, Portable Digital Scales*, 2020. [Online]. Available: https://www.chardermedical.com/innovation.htm. [Accessed: 17-Apr-2021].
[8] J. M. a. B. T. S Ekins, "In silico pharmacology for drug discovery: methods for virtual ligand screening and profiling," NCBI, 4 June 2007. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1978274/. [Accessed 23 April 2021].
[9] "Electronics Club," [Online]. Available: https://electronicsclub.info/impedance.htm. [Accessed 23 April 2021].
[10] Clem Asogwa, Assefa Teshome, Stephen F Collins, Daniel T.H. Lai, "A Circuit Model of Real Time Human Body Hydration," ResearchGate, October 2015. [Online]. Available: https://www.researchgate.net/publication/283048641_A_Circuit_Model_of_Real_Time_Human_Body_Hydration. [Accessed 23 April 2021].
[11] O. Jones, "Anatomical Planes," TeachMeAnatomy , 6 January 2018. [Online]. Available: https://teachmeanatomy.info/the-basics/anatomical-terminology/planes/. [Accessed 23 April 2021]
[12] "602030 mini Lipo Rechargeable Lithium Battery 300mAh 3.7V Bluetooth MP3 Wireless Card Audio Recorder Li-ion Cell Batteries," Aliexpress, [Online]. Available: https://www.aliexpress.com/item/1005001310236068.html?src=google&albch=shopping&acnt=708-803-3821&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&&albagn=888888&isSmbAutoCall=false&needSmbHouyi=false&albcp=7386. [Accessed 2 April 2021].
[13] iStock, [Online]. Available: https://www.istockphoto.com/illustrations/gender-symbol. [Accessed 23 April 2021].
[14] Wei Chen, "Body Composition Analysis by Using Bioelectrical Impedance in a Young Healthy Chinese Population: Methodological Considerations," 2017.
[15] Robert Ross, Luc Leger, Paul Martin, Roch Roy, "Sensitivity of bioelectrical impedance to detect changes in human body composition," the American Physiological Society, 1989.
[16] T. K. Bera, "Bioelectrical Impedance Methods for Noninvasive Health Monitoring: A Review," [Online]. Available: https://www.hindawi.com/journals/jme/2014/381251/. [Accessed 20 April 2021].
[17] [Online]. Available: https://www.healthline.com/health/sodium-blood. [Accessed 24 April 2021].
[18] “RN4871-V/RM118 - BLE MOD W/ANTENNA, 2.442MHZ, 0.1DBI,” *Newark*. [Online]. Available: https://canada.newark.com/microchip/rn4871-v-rm118/ble-mod-w-antenna-2-442mhz-0-1dbi/dp/01AC4946?s_kwcid=AL%218472%213%21507454857750%21%21%21u%21334507183893%21&mckv=_dc%7Cpcrid%7C507454857750%7Cplid%7C%7Ckword%7C%7Cmatch%7C%7Cslid%7C%7Cproduct%7C01AC4946%7Cpgrid%7C122092002120%7Cptaid%7Cpla-334507183. [Accessed: 25-Apr-2021].
[19] “Intel Pentium Dual Core Processor,” *Amazon.ca*. [Online]. Available: https://www.amazon.com/Intel-Pentium-Dual-Core-Processor-800MHz/dp/B0010TCK3A/ref=sr_1_19?_encoding=UTF8&c=ts&dchild=1&keywords=Computer+CPU+Processors&qid=1616791998&s=pc&sr=1-19&ts_id=229189. [Accessed: 24-Apr-2021].
[20] “MCP4822-E/P,” *DigiKey*. [Online]. Available: https://www.digikey.ca/en/products/detail/microchip-technology/MCP4822-E%2FP/951465?utm_adgroup=Data+Acquisition+-+Digital+to+Analog+Converters+%28DAC%29&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Integrated+Circuits+. [Accessed: 25-Apr-2021].
[21] “4.0US $ 41% OFF: 602030 mini Lipo Rechargeable Lithium Battery 300mAh 3.7V Bluetooth MP3 Wireless Card Audio Recorder Li ion Cell Batteries: Replacement Batteries: - AliExpress,” *aliexpress.com*. [Online]. Available: https://www.aliexpress.com/item/1005001310236068.html?src=google&albch=shopping&acnt=708-803-3821&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&&albagn=888888&isSmbAutoCall=false&needSmbHouyi=false&albcp=7386. [Accessed: 25-Apr-2021].
[22] “Cortex-M4,” *Arm Developer*. [Online]. Available: https://developer.arm.com/ip-products/processors/cortex-m/cortex-m4. [Accessed: 18-Apr-2021].
[23] J.-L. Aufranc, “Samsung S3FBP5A Bio-Processor Targets Fitness Tracking Wearables - CNX Software,” *CNX Software - Embedded Systems News*, 09-Jun-2017. [Online]. Available: https://www.cnx-software.com/2015/12/30/samsung-s3fbp5a-bio-processor-targets-fitness-tracking-wearables/. [Accessed: 18-Apr-2021].
[24] “Apple Watch Series 5,” *GSMArena*. [Online]. Available: https://www.gsmarena.com/apple_watch_series_5-9859.php. [Accessed: 18-Apr-2021].

Final Presentation Hydration device design Transcript

Project: Hydration device

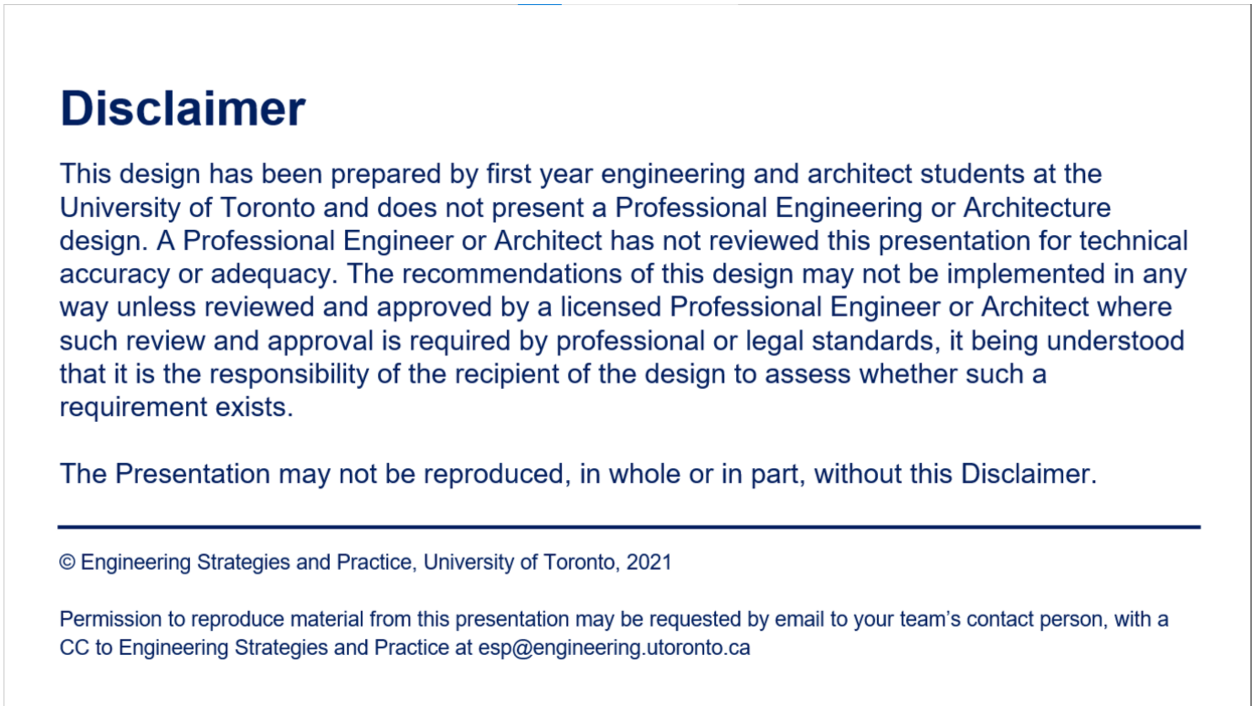
All Presenters: Danial Khan, Melika Joulaei, Rohan Patel, Shachi Desai, Ines Qian, Srinidhi Shankar

Slide Number: 1



[Rohan Patel] This is our team's presentation for the body hydration sensor project. We will be presenting our bioelectric impedance design and reasons why we believe that this would be the most effective design on the market right now. But first, a quick disclaimer.

Slide Number: 2



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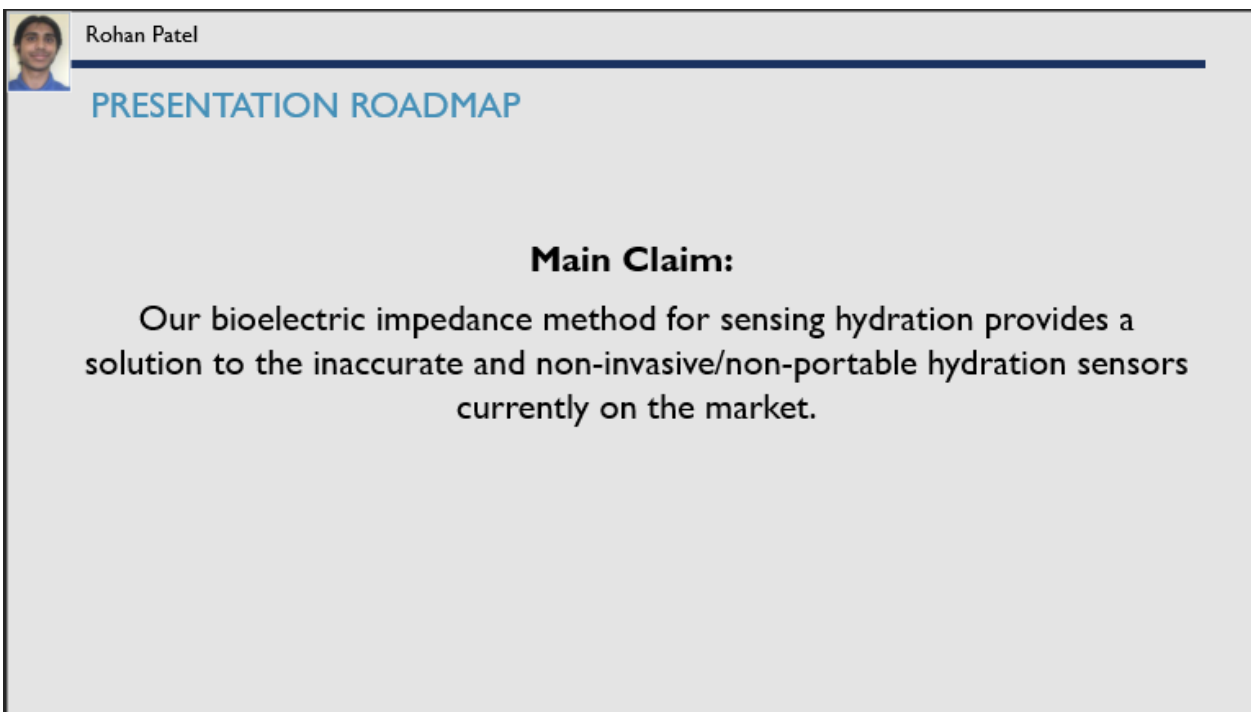
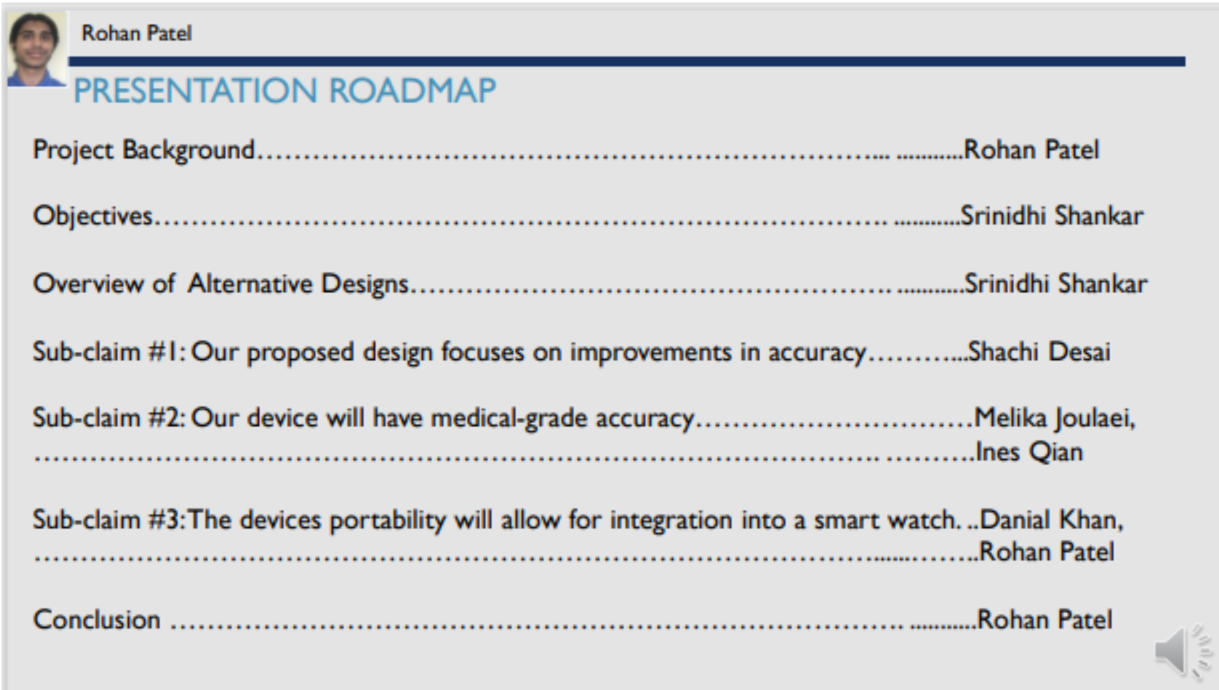
Slide Number: 3



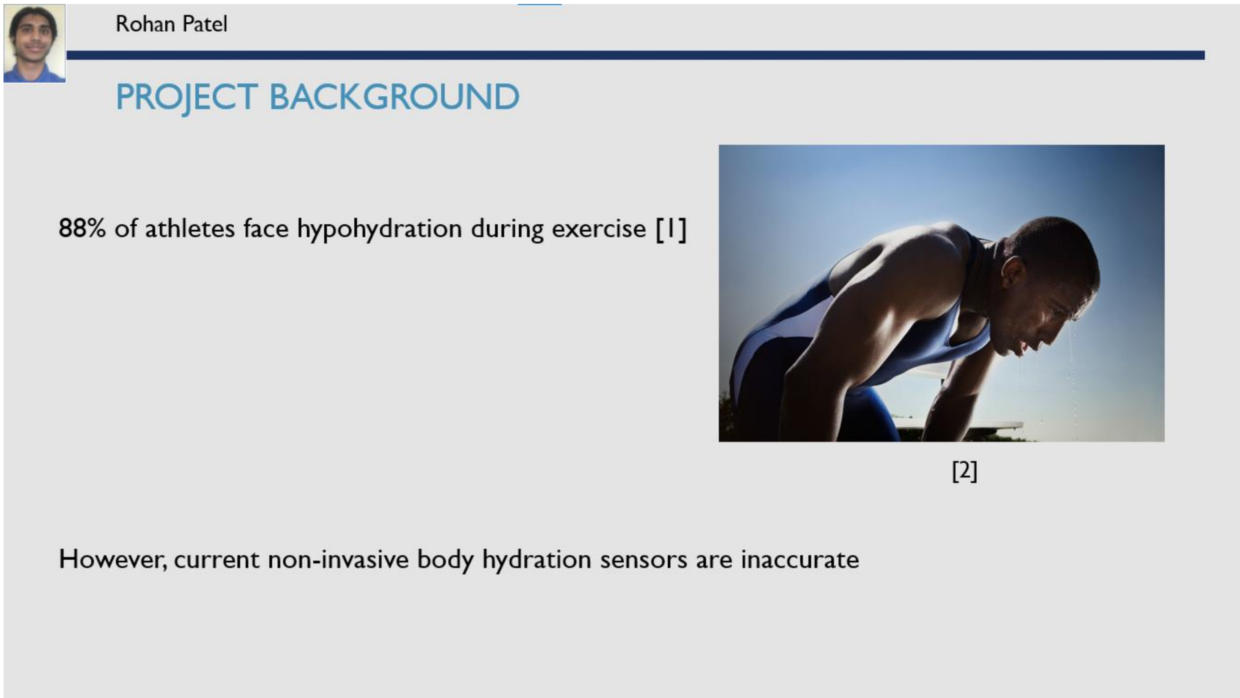
[Rohan Patel] Our team claims that the bioelectric impedance design that we have developed best meets the objectives and requirements of this project.

Slide Number: 4



[Rohan Patel] We will first introduce the project background and objectives for the project. Then present the three designs which we have developed as solutions. We will then provide and in-depth explanation of the bioelectric impedance technology and then state how this design meets the measures of success for this project.

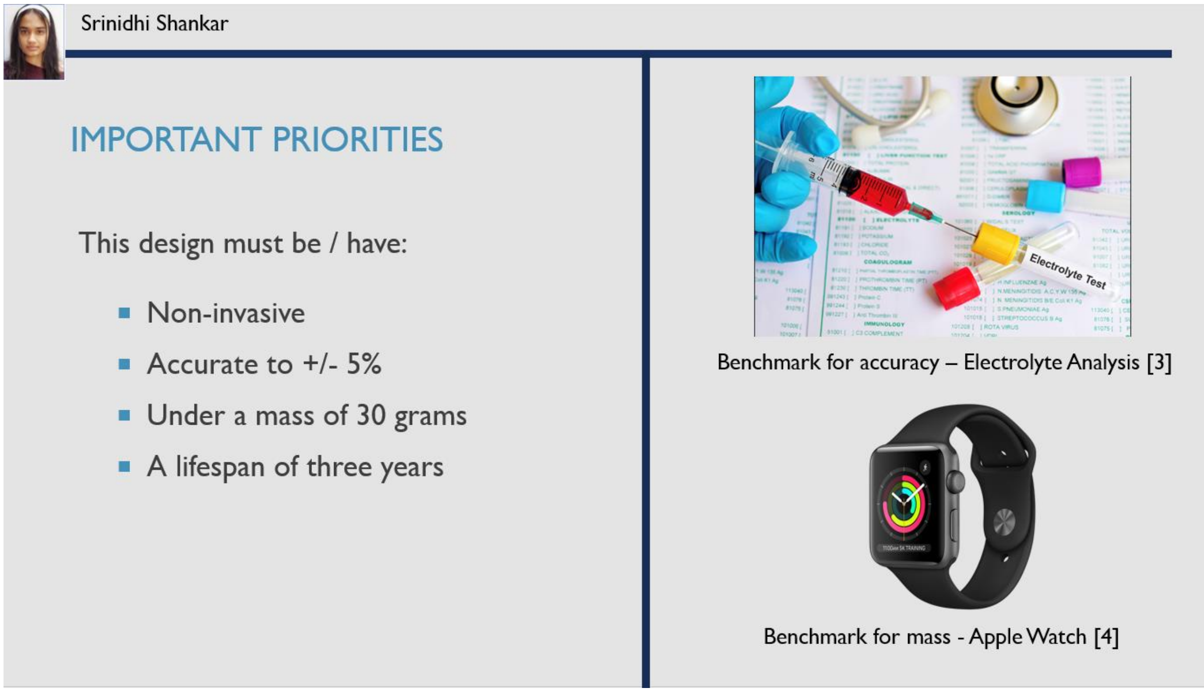
Slide Number: 5



[Rohan Patel] I will now begin by introducing the background to this project. As you know, athletes are very health conscious, many will make sure to exercise everyday, eat enough protein for muscle development, and closely monitor their calories. So, can we assume that they also monitor their hydration, since this is such an important part of living a healthy lifestyle? Unfortunately not. In fact, research has proven that 88% of athletes are hypohydrated. And current solutions on the market are not accurate enough to provide athletes with a clinically relevant measure of their hydration. So, our team has developed a design for a highly accurate, portable, medical grade hydration sensor,

I will now pass it off to Srinidhi, to explain the important priorities for this design.

Slide Number: 6

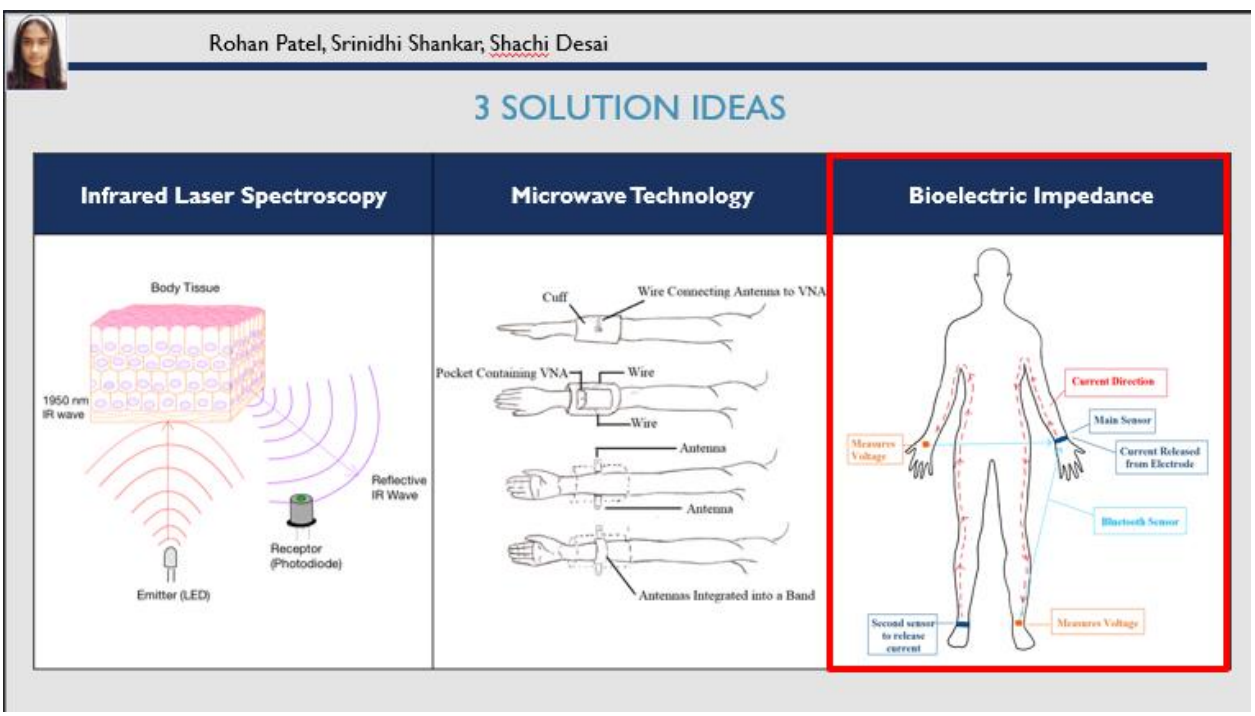


[Srinidhi] Thank you, Rohan. I now want to highlight the priorities of our design. These are the requirements that led to the development of our three alternative designs. The design must be noninvasive. This means that no part of the design can physically penetrate the skin. This is a constraint; so, every viable design must meet this requirement. Secondly, the design must not have an error rate of over +/-5%. This will be benchmarked against results collected from electrolyte analysis. Electrolyte analysis uses blood tests to measure hydration, proven to be extremely accurate. +/-5% is an absolute maximum; so, the accuracy of feasible designs may vary. The design must be under a mass of 30 grams to ensure its portability. This is benchmarked against an Apple Watch. 30 grams is an absolute maximum; so, feasible designs may vary in mass. Finally, the design must have a lifespan of 3 years and maintain the same level of quality within this timeline. This will be measured by inspecting the device over three years. This is a constraint; so, any design that does not meet this is considered not viable.

Slide Number:7

[Srinidhi] We are now going to introduce our three alternative designs.

Slide Number: 8



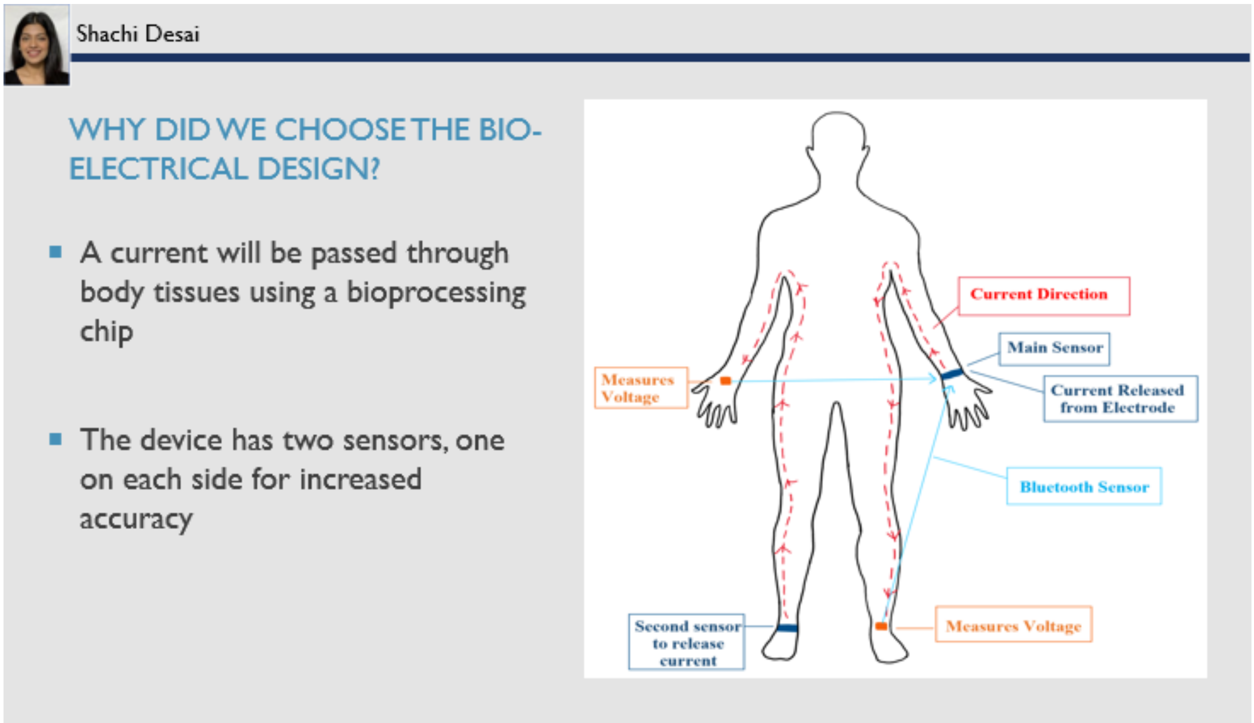
[Srinidhi] We will now present the 3 alternative designs. The entire design space was explored through various idea generation tools. These were then selected as top 3 based on how well they met the important priorities that were just stated. The first alternative design is Infrared based technology. This uses light emitted at a wavelength of 1950nm. A photodiode receives this light once it has been absorbed and reflected by water in muscle tissue. The intensity of the reflected wavelength is inversely proportional to the individual's water content. The wavelength of 1950 nm prevents the device from measuring skin hydration, which is the main source of error in existing infrared solutions. The next alternative design is microwave technology. Two antennas would be placed on either side of the person's arm. Calculations would be performed to determine the permittivity of the microwaves through the body tissue. Permittivity is a property of microwaves proven to be related to body weight loss due to water loss with a correlation of 64%. Bioelectrical impedance is the proposed solution. Bioelectric impedance involves placing electrodes on the surface of the skin to flow current through the blood. The body tissues pose a resistance, and a relationship has been defined between this resistance and the overall hydration. This solution was chosen as it is the most accurate of the three solutions, as well as more cost efficient.

Slide Number: 9

SUBCLAIM 1: WE HAVE A PROPOSED BIOELECTRIC DESIGN THAT FOCUSES ON IMPROVEMENTS IN ACCURACY.

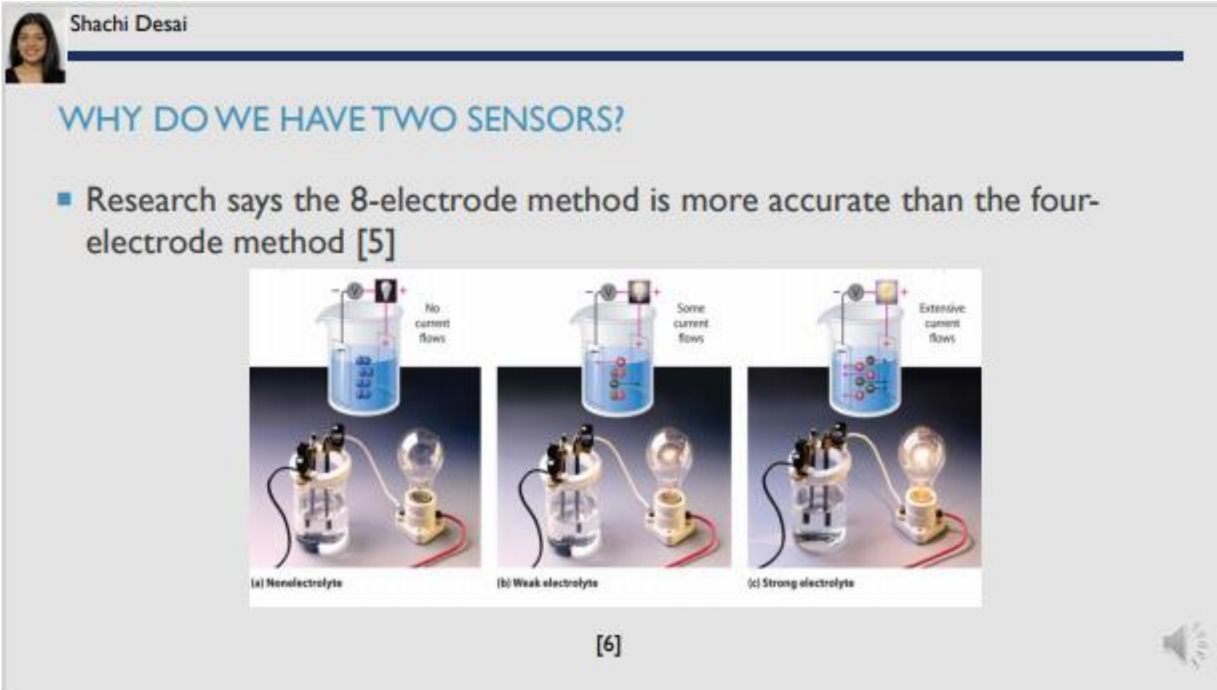
[Shachi Desai] Now we will be looking at subclaim 1, which talks about the proposed bioelectric design and the improvements made to increase accuracy.

Slide Number: 10



[Shachi Desai] So, why did we choose the bioelectrical design. In this device, current will be passed through using a bioprocessing chip. This chip will then release the current from the sensors. Once the current is released, it will follow a path that is similar to the user's blood stream. When this current reaches the patches that measure voltage drop, it will provide the level of resistance through which the current is passed. Each of the two sensors employs the 4-electrode method, where one pair of electrodes release current and the second pair of electrodes are responsible for measuring the voltage drop.

Slide Number: 11

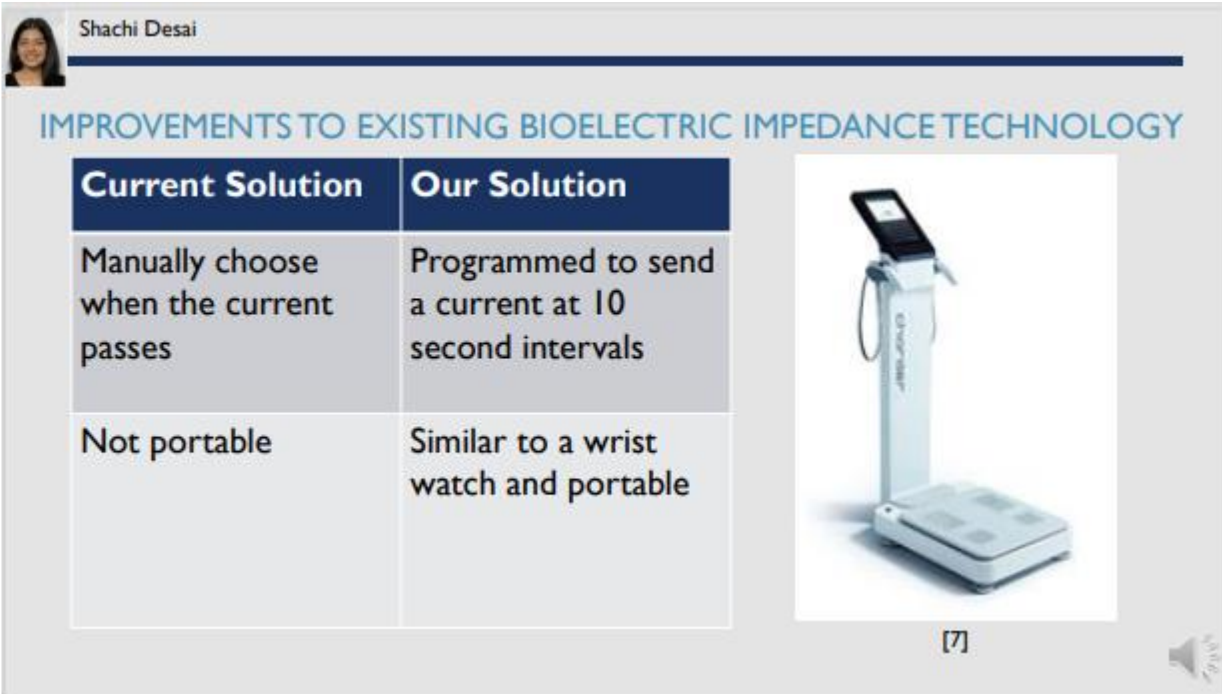


[Shachi Desai] Why does our design include two sensors?

Research shows that the 8-electrode Bioimpedance method is more accurate than the 4-electrode method. And so, we decided to separate the 8 electrodes onto each side of the body, which is what resulted in the two sensors. This will ensure that the entire body is equally measured and will give us more accurate results. From the information we receive from the 8-electrode method, we know that if the results show a resistivity level that is higher than normal, than this means that the user is dehydrated.

And we know this because when the user is well hydrated, the tissues in the user's body have a higher amount of fluid, which also means they have a high amount of electrolytes which results in high conductivity. And we know that high conductivity is what results in low resistivity

Slide Number: 12



[Shachi Desai] improvements made to the existing bioelectric impedance technology

We have made changes to the original design to increase accuracy and portability of the device, as well as receive real time measurements.

In the current solution, the user is required to manually decide when the current will pass through, and the measurement will be taken. In our device, the sensor will be programmed to send a current at 10 second intervals.

Another change we made is that the current solution is not portable. - if you look at the image on the slide you can see that the current design is similar to a weighing scale, and it does give the user freedom to play sports or perform other activities while their hydration is being measured. And so, to make sure our design is portable and does not restrict the user, we have made the design very similar to a wristwatch.

Slide Number: 13

Ines Qian

SUBCLAIM 2: OUR DEVICE WILL HAVE MEDICAL-GRADE ACCURACY

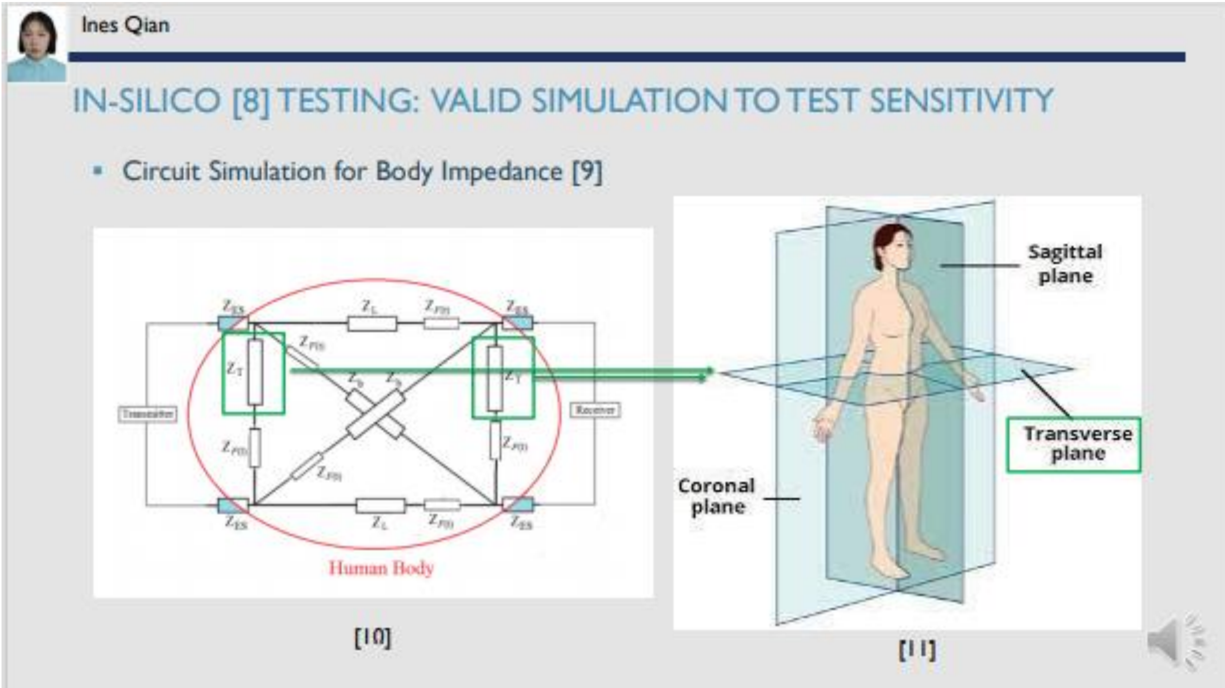
The team has detailed plans for measurement of the proposed design's success in sensitivity and accuracy, so the team can ensure that the design will be accurate for all possible user groups and can be implemented.

* Sensitivity → In-silico Testing

* Accuracy → Clinical Testing

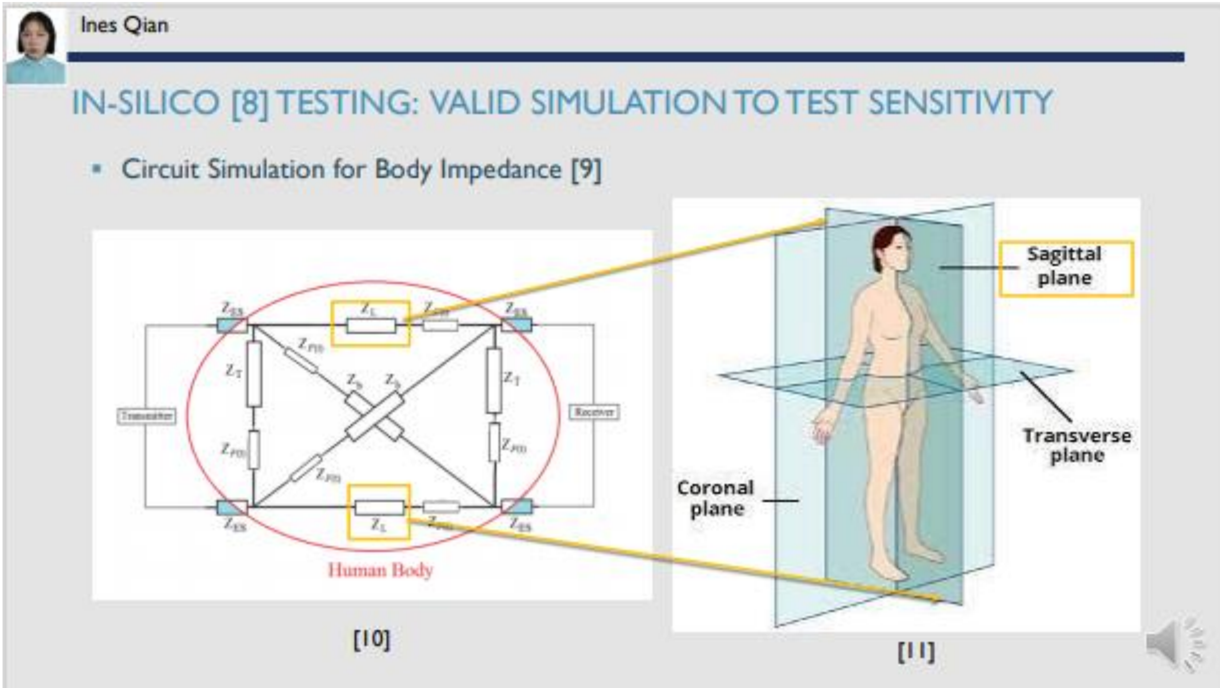
[Ines Qian] After developing the conceptual design, the team has also carried out plans to measure its success in sensitivity and accuracy, so the team can ensure that the design will be accurate for all possible user groups and can be implemented.

Slide Number: 14



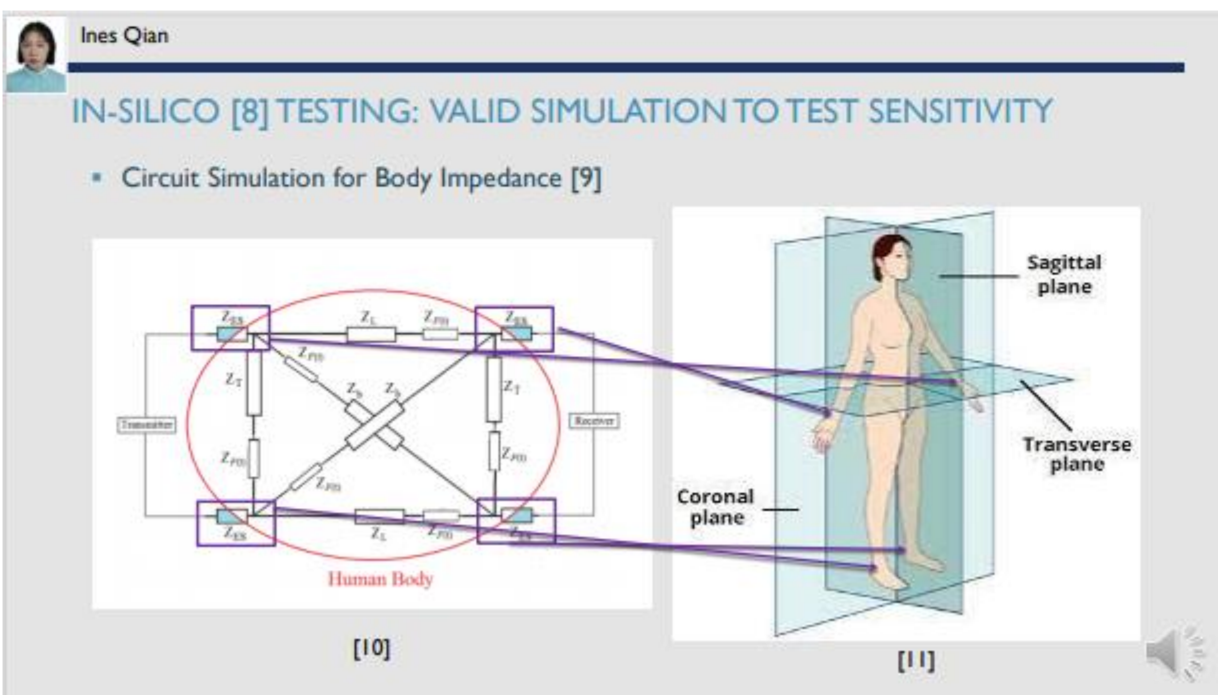
[Ines Qian] I will first elaborate on the in-silico testing, which means conducting experiments on computers, that will ensure an ideal sensitivity for the design. To set up the experiment, the team plans to use a circuit that simulate the human body by its impedance developed by Dr. Clem Asogwa. Impedance is the tissues' property to resist electrical current. This model is a strong and valid model for the entire body simulation because it accounts for the transverse,

Slide Number:15



[Ines Qian] the longitudinal,

Slide Number: 16



[Ines Qian] the skin surface impedance,

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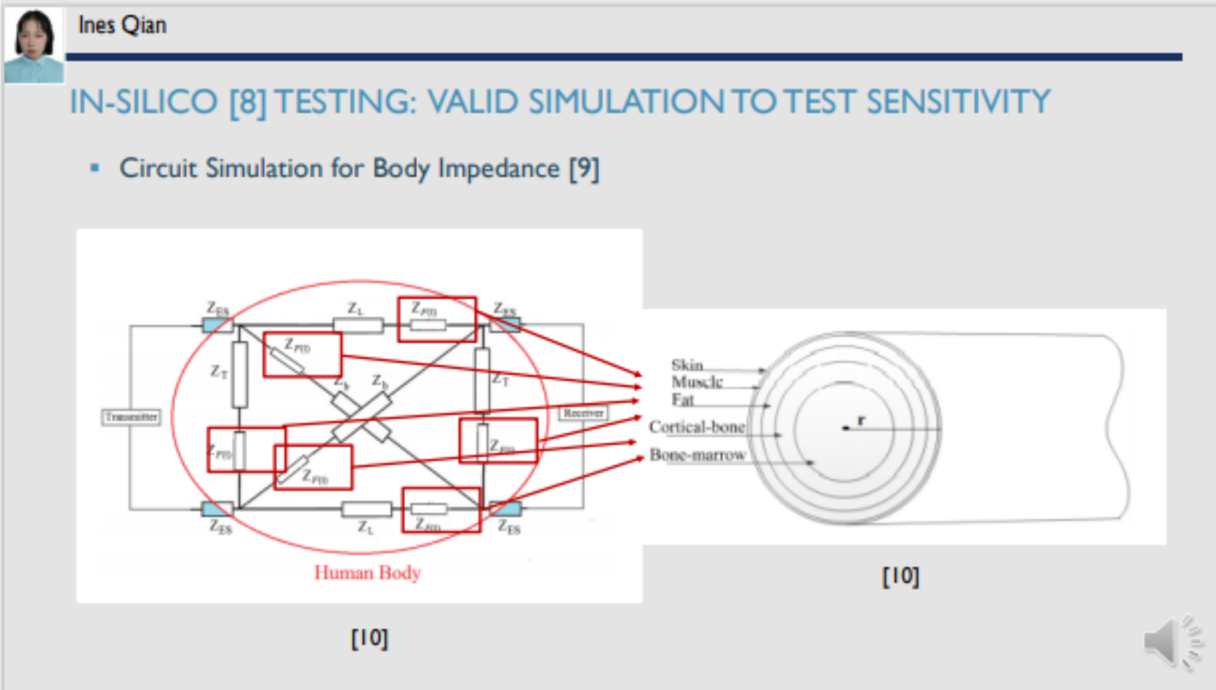
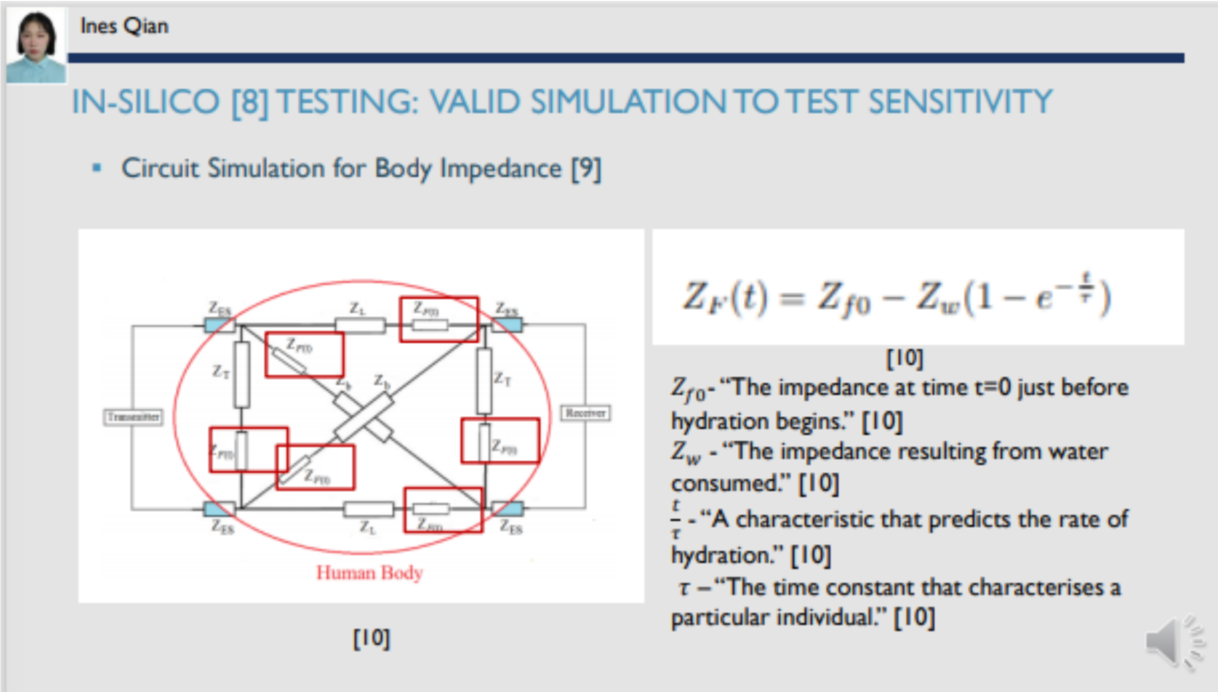


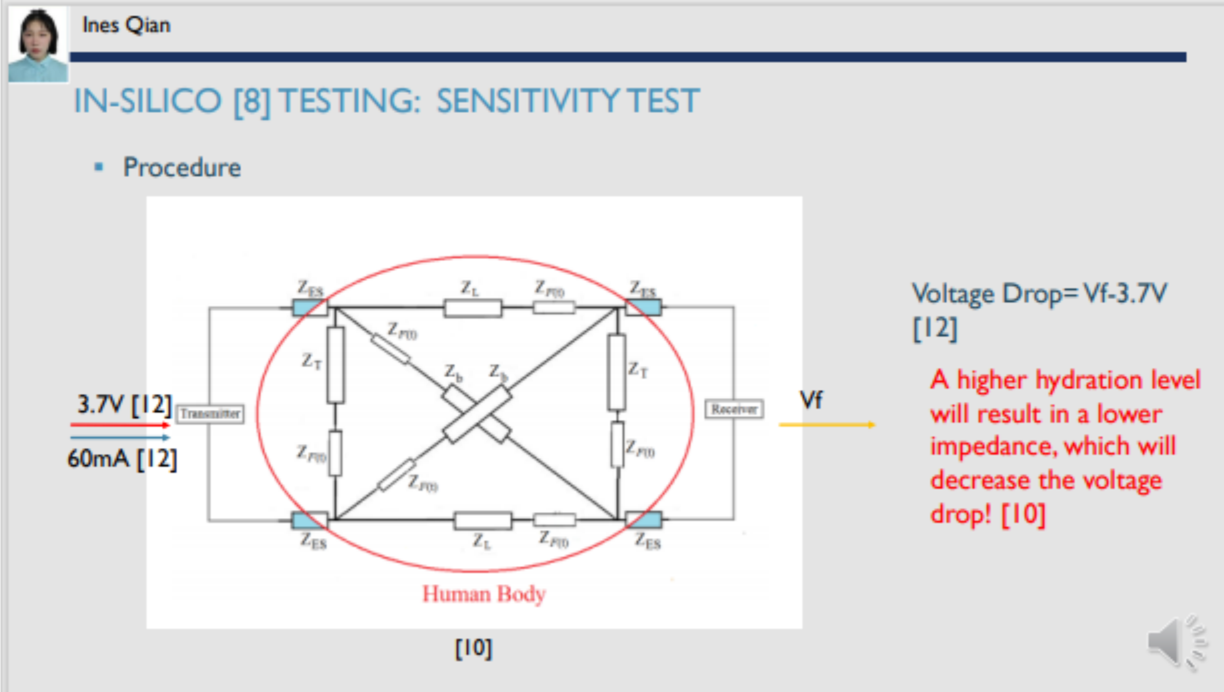
[Ines Qian] as well as the impedance of deeper body tissues, as illustrated in the graph on the right. It is found that the model has covered all the possible impedances of body tissues. As a result, we can conclude that this model is a valid model!

Slide Number: 18



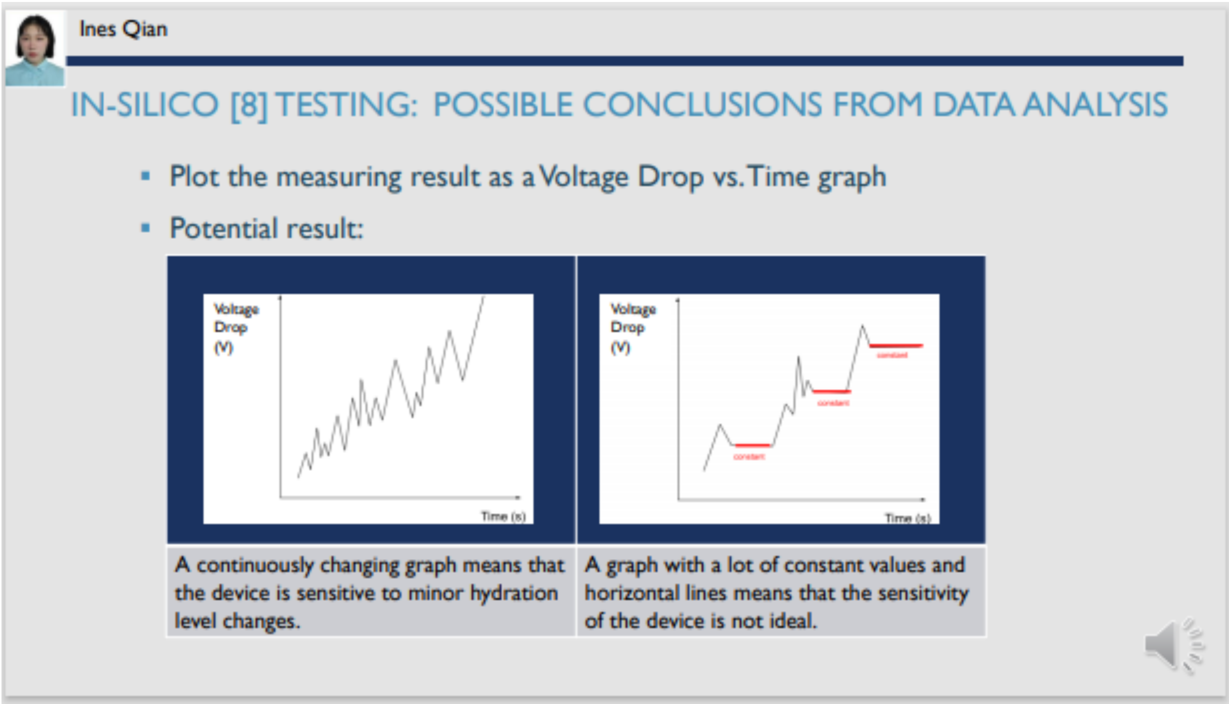
[Ines Qian] At the same time, the impedance of deep body tissues takes the dynamic of body hydration regulation into consideration by having the impedance as a function of time.

Slide Number: 19



[Ines Qian] During the experiments, a voltage of 3.7V and a current of 60mA, which is the amount of voltage and current the team's design will pass to human body, will be passed to circuit. The voltage at the other end of the circuit will also be measured. The difference between which is the voltage drop for the circuit. A higher hydration level will result in a lower impedance, which will decrease the voltage drop.

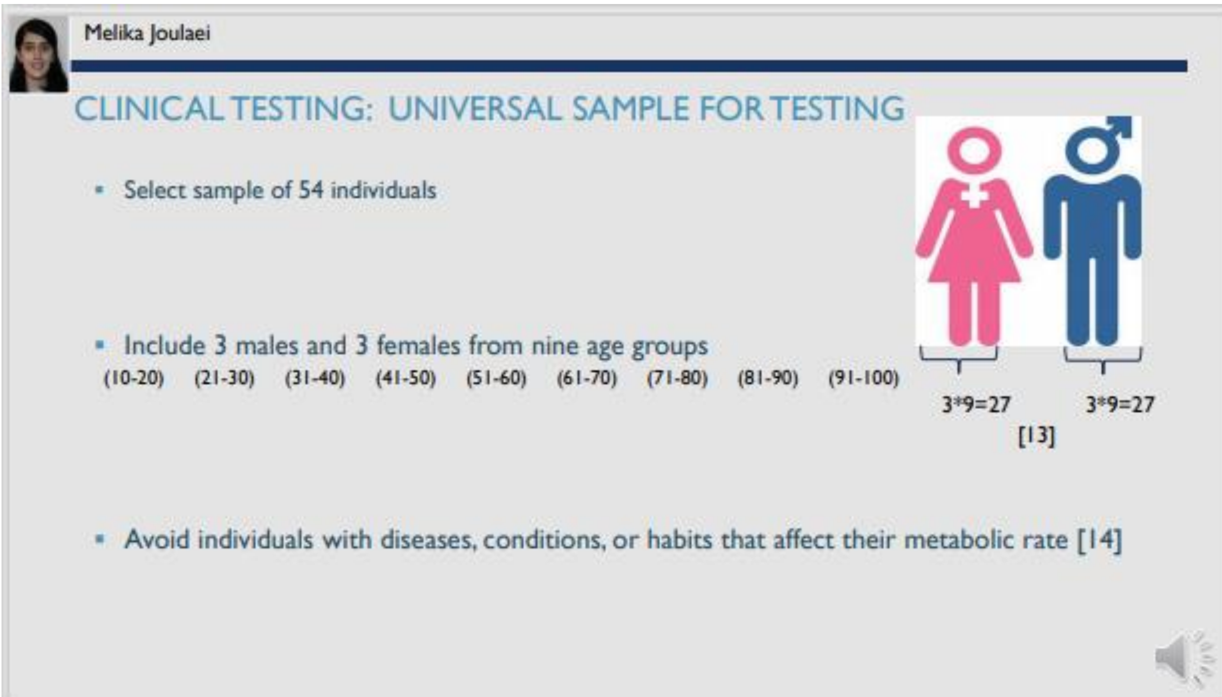
Slide Number:20



[Ines Qian] The voltage drop will then be plotted onto a voltage drop vs. time graph. Since the impedances keep changing with time, the voltage drop graph of a sensitive device will also change continuously; whereas graphs with many horizontal lines (constant voltage drop over time) will indicate that the sensitivity of the device is not ideal. The graphs on the screen are not based on real experimental results, but are just logistic graph drawn by myself.

Now I will pass to Melika to talk more about the clinical testing that measures the accuracy of the design.

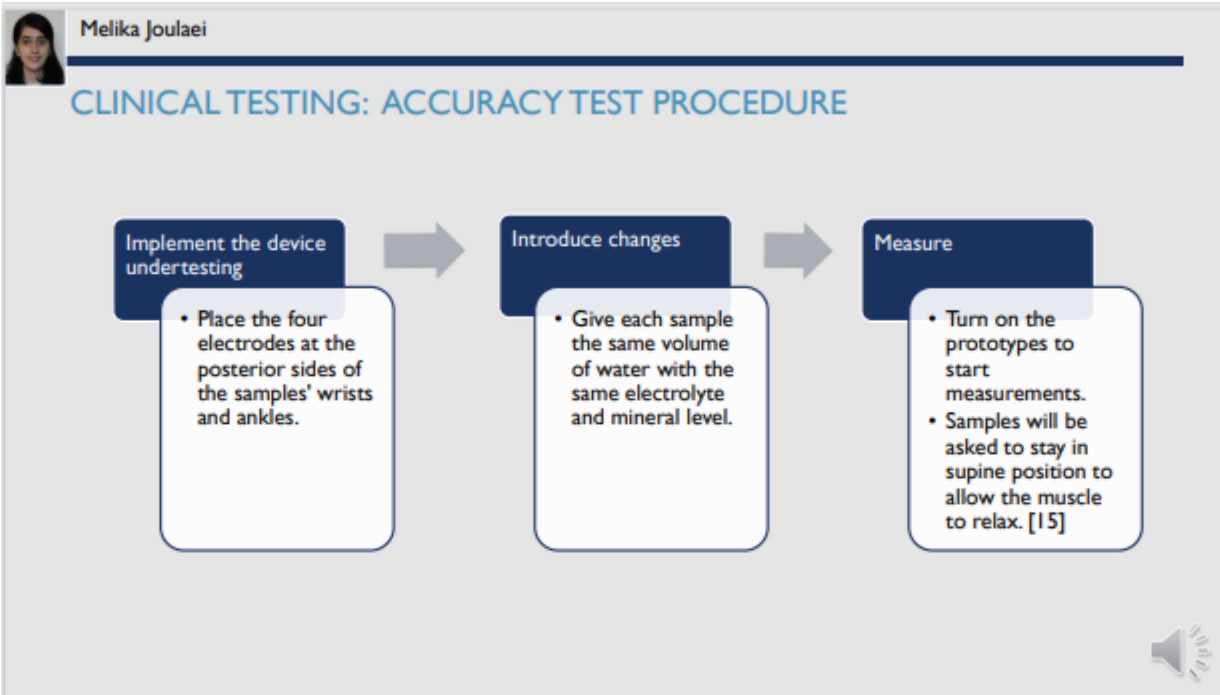
Slide Number 21



[Melika Joulaei] Thank you, Ines. Ok. So far, we have explained circuit simulation as a way to test the sensitivity of the design. Now, I will explain and introduce a clinical testing which is going to measure the accuracy of our proposed hydration sensor on a sample of individuals

As Srini stated earlier in the presentation, one of objectives is universality, which means that the design must be within 5% accuracy all age groups, both females and males. And that is why we decided to include 3 males and 3 females from 9 age groups as you can see on the slide. We also decided that individuals within the sample must not have any disease. They must also not smoke, drink alcohol or use drugs as these conditions and habits affect the metabolic rate and can interfere with the results of the experiment.

Slide Number 22

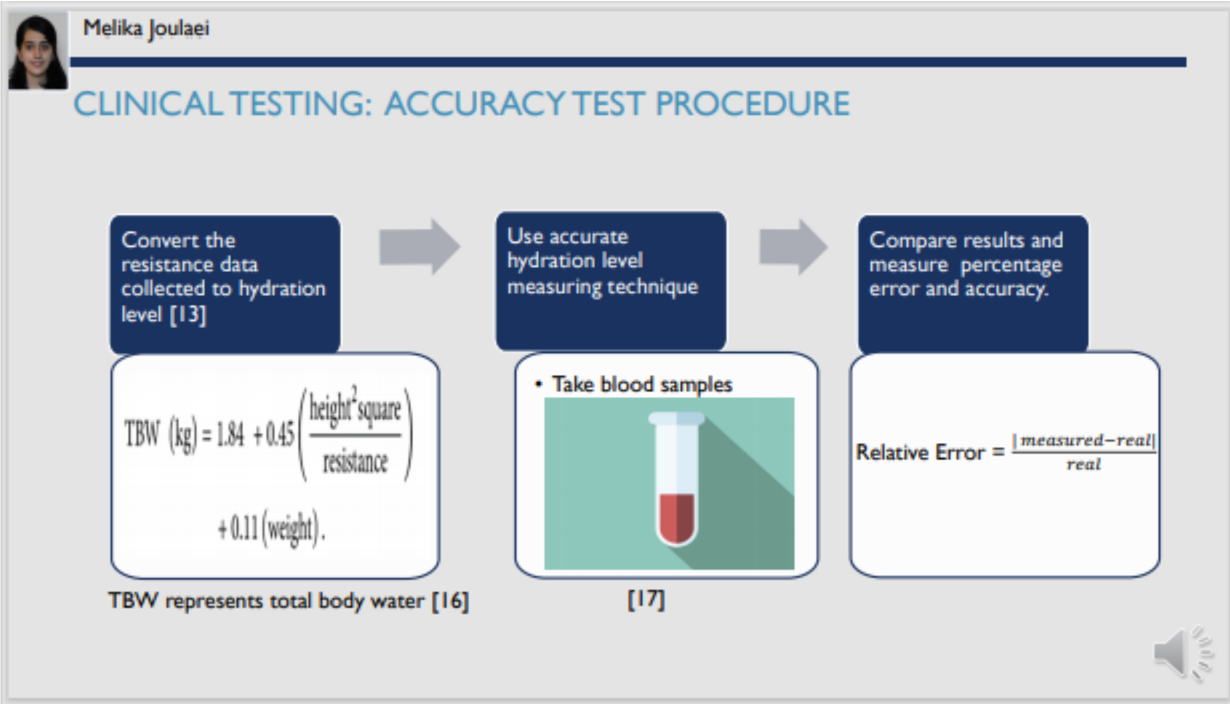


[Melika Joulaei] Now, how will the test work?

To carry out the experiment, we will need: a prototype of our Bioelectrical Impedance Technology, we also need a bed, water, and measuring cups.

Once the sample has been selected, we can start the experiment by putting the four electrodes of the prototype to the posterior sides of the wrists and ankles of the individuals. Following that we will give water samples of the same type and same volume to each of the individuals. Once the water samples are given, then we will have to start the measurements by turning on the prototype. In this time, we ask each of the individuals to stay in supine positions so that can allow their muscles to relax.

Slide Number 23



[Melika Joulaei] Once resistance data have been obtained using the prototype, we have to convert it to hydration level using the formula on the left side of the slide. Then we take blood samples of individuals and using electrolyte analysis we find the accurate hydration level of each individual. By using the relative error formula which can see on the right side, we will compare the results of the prototype to the accurate s and find the error bound. This way we will measure the accuracy of the hydration sensor design. Now I will pass it to Danial.

Slide Number 24

[Danial Khan] Now we would like to focus on subclaim 3, which focuses on the devices portability and allows us to integrate it into a smartwatch comparable size.

Slide Number: 25

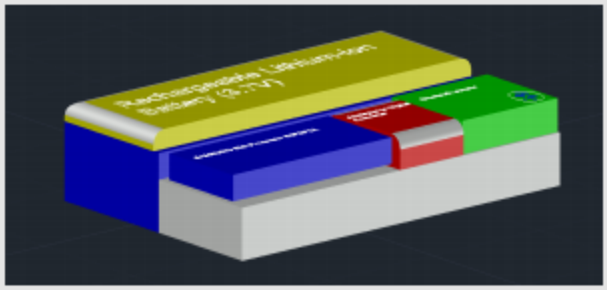
Danial Khan

PORTABILITY

- Prioritized objective → need a non-invasive design having a mass of under 30g
  - Therefore, essential measure of success

Table 2: List of parts with associated masses

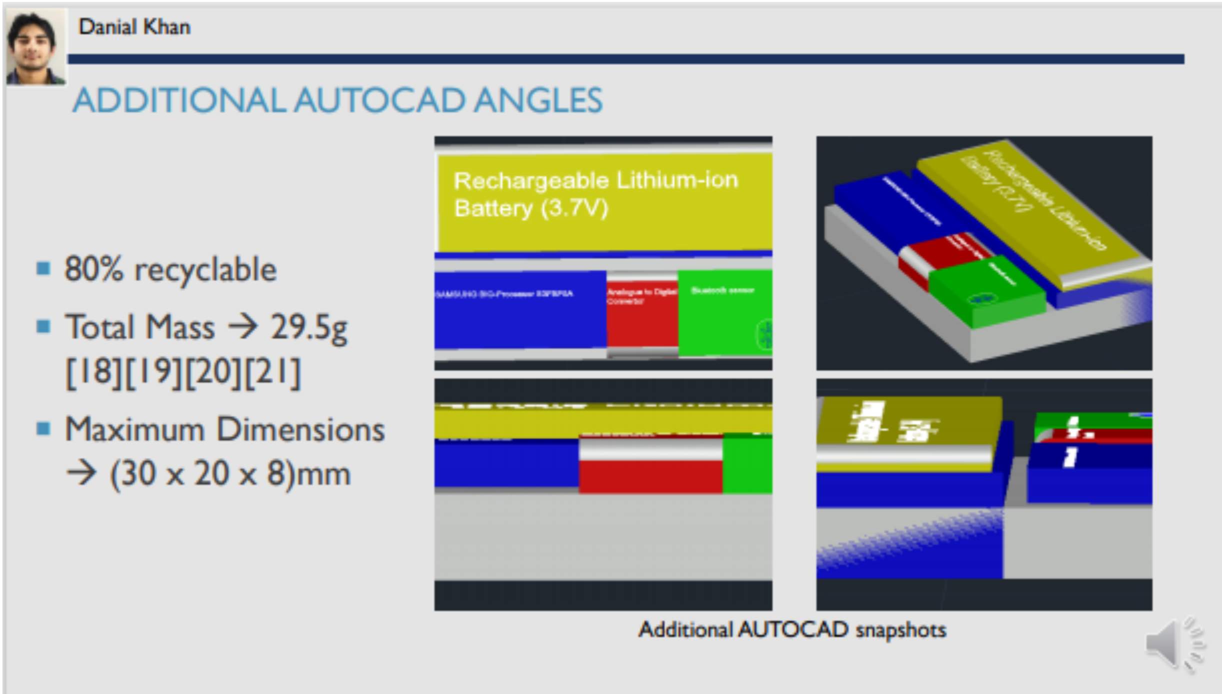
Part	Mass (g)
Bluetooth module	10 [18]
Samsung Bio-processor	6 [19]
Analogue to Digital convertor	3 [20]
3.7V Lithium Ion battery	10.5 [21]
TOTAL	29.5



Angle #1 for AUTOCAD model

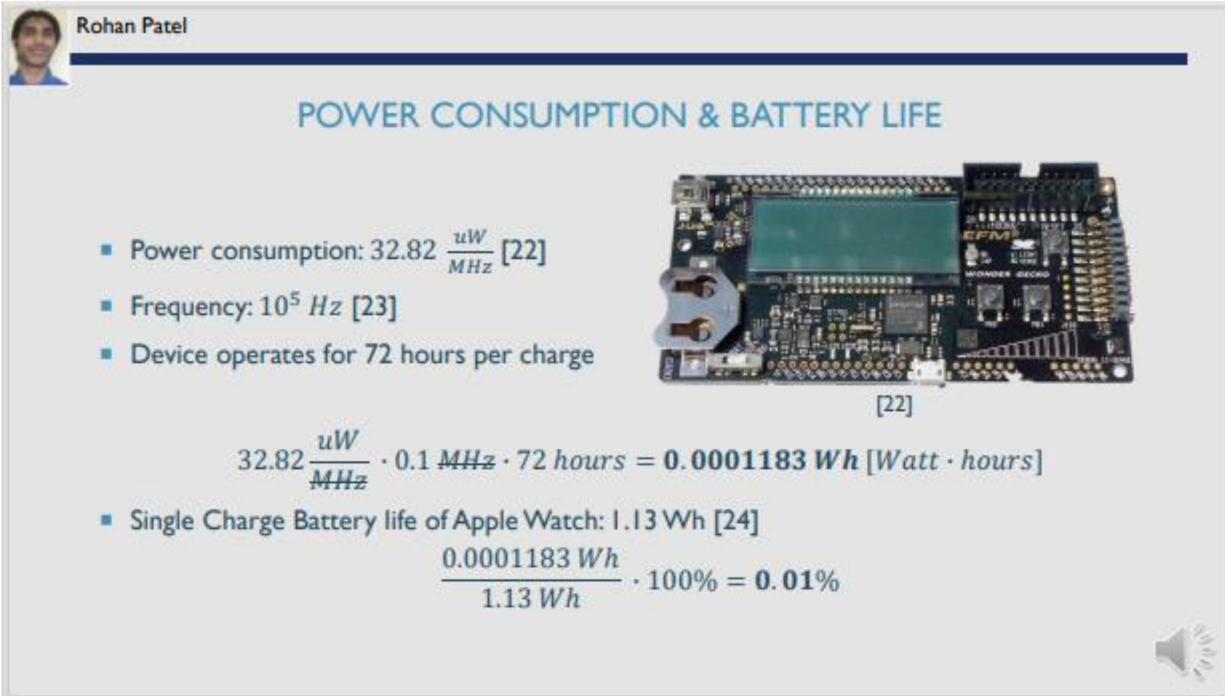
[Danial Khan] Something we would like to emphasize here to prove our subclaim 3 is that our prioritized objective is portability because we need a non-invasive design having a mass of under 30g. We would consider this as our measure of success. Shown in table 2 is a list of parts that has the associated masses, and we have a total of about 29.5 grams. Clearly, we have met our metric of success of under 30g since it is 29.5.

Slide Number: 26



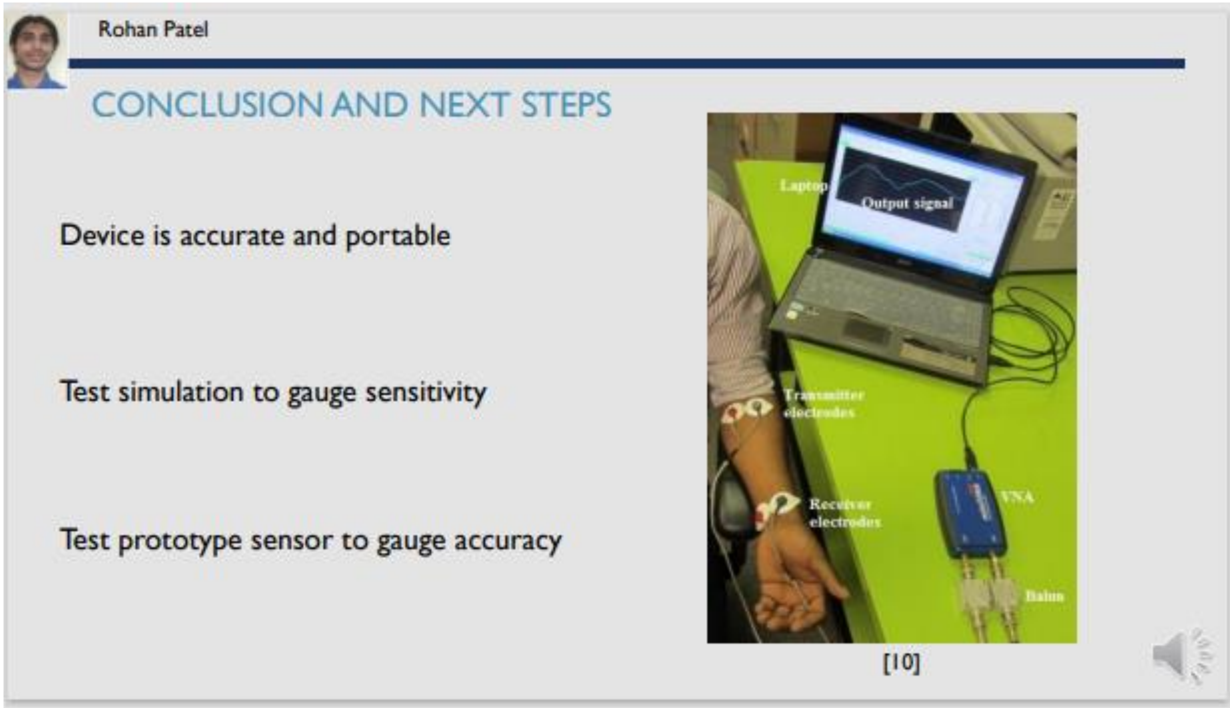
[Danial Khan] Now I'd just like to highlight the additional angles that we have provided in this slide. Specifically, we would like to focus on the four parts that make up this entire autocad model, and overall will make up the sensor. So, first highlighted in green, there is that Bluetooth sensor that transfers information to the main device so that it can be used in our calculations for the end user. Then there is the Samsung bio-processor, highlighted in blue that allows us to use electrodes to initiate that current flow. In red, there is an analogue to digital convertor which allows us to obtain a readable voltage drop value in the end because the whole purpose of this project [design] is to allow the current to flow through your body [different parts of your body] and eventually reach a point where we can measure the voltage drop from the initial to the final position. Therefore, we need it to be readable. Finally, there is that 3.7V lithium-ion battery which powers this processor. Please keep in mind that this model is the sensor that we would be allowing the next team [strap design] to use. For example the wrist watch or the ankle strap. This design has a maximum dimension of (30 x 20 x 8)mm. This overall slide, and the portability aspect of the design focuses on the importance of the consumer first and how they will be seeing this product. Really, the first judgement of this product will be based on portability.

Slide Number: 27



[Rohan Patel] Expanding on the portability, our design should also have a minimal power consumption so that it can be integrated into a smart watch like design. Using the power consumption of the device's processor and the duration that the device will be in operation for, the total power consumption for the device is calculated here. Comparing this to the battery life of an Apple Watch, this device only consumes .01% of the battery's single charge life. Meaning our device will operate for long periods of time on a single charge.

Slide Number: 28

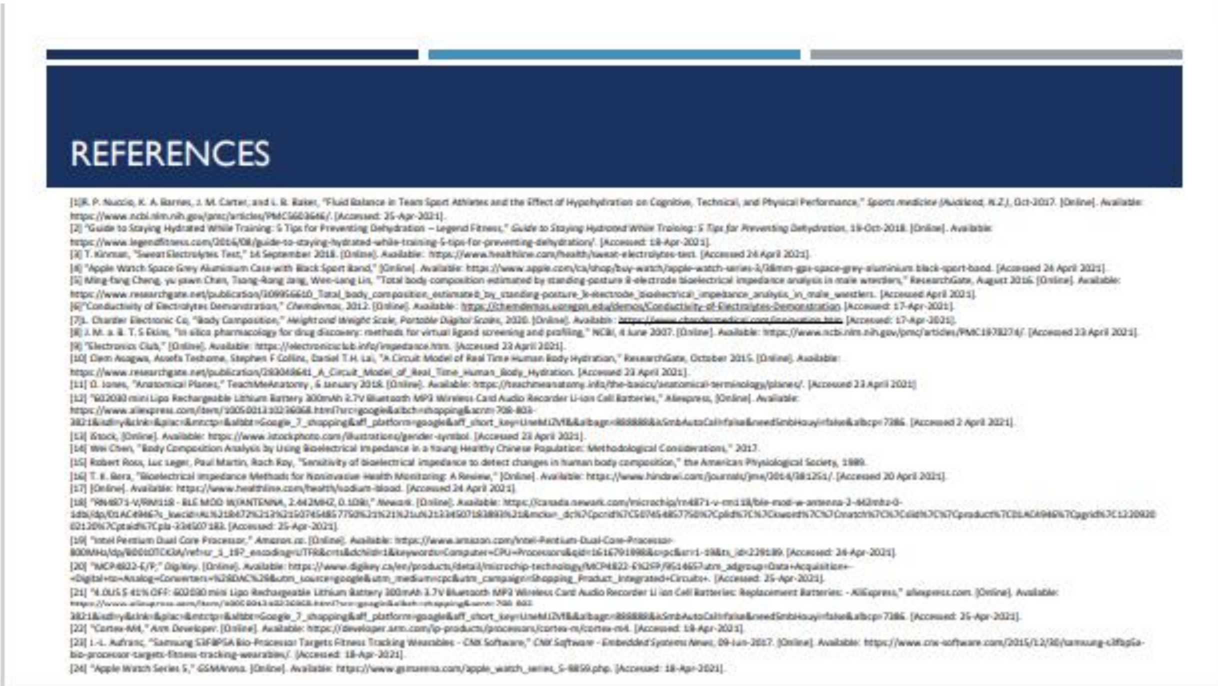


[Rohan Patel] The novel version of bioelectric impedance technology that our team is proposing will solve the problem that wearable hydration sensors in the market right now are inaccurate. This design is accurate due to the improvements our team has made to the existing technology. This sensor design is also integrable into a smart watch sized device due to its low power consumption and small size.

The next steps required to bring this sensor into the market are the simulations and experimental procedures to gauge the sensitivity and accuracy of the design. At this point in the design process, the technology behind the body hydration sensor will be developed and is ready for use by athletes.

Thank you for your support and your time.

Slide Number: 29



[No Speaker, slides play for 2 second each] References list repeated here for clarity.

Reference List:

[1]R. P. Nuccio, K. A. Barnes, J. M. Carter, and L. B. Baker, “Fluid Balance in Team Sport Athletes and the Effect of Hypohydration on Cognitive, Technical, and Physical Performance,” *Sports medicine (Auckland, N.Z.)*, Oct-2017. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5603646/. [Accessed: 25-Apr-2021].

[2] “Guide to Staying Hydrated While Training: 5 Tips for Preventing Dehydration – Legend Fitness,” *Guide to Staying Hydrated While Training: 5 Tips for Preventing Dehydration*, 19-Oct-2018. [Online]. Available: https://www.legendfitness.com/2016/08/guide-to-staying-hydrated-while-training-5-tips-for-preventing-dehydration/. [Accessed: 18-Apr-2021].

[3] T. Kinman, "Sweat Electrolytes Test," 14 September 2018. [Online]. Available: https://www.healthline.com/health/sweat-electrolytes-test. [Accessed 24 April 2021].

[4] "Apple Watch Space Grey Aluminium Case with Black Sport Band," [Online]. Available: https://www.apple.com/ca/shop/buy-watch/apple-watch-series-3/38mm-gps-space-grey-aluminium black-sport-band. [Accessed 24 April 2021].

[5] Ming-fang Cheng, yu yawn Chen, Tsong-Rong Jang, Wen-Lang Lin, "Total body composition estimated by standing-posture 8-electrode bioelectrical impedance analysis in male

wrestlers," ResearchGate, August 2016. [Online]. Available: https://www.researchgate.net/publication/309956610_Total_body_composition_estimated_by_standing-posture_8-electrode_bioelectrical_impedance_analysis_in_male_wrestlers. [Accessed April 2021].

[6]“Conductivity of Electrolytes Demonstration,” *Chemdemos*, 2012. [Online]. Available: https://chemdemos.uoregon.edu/demos/Conductivity-of-Electrolytes-Demonstration. [Accessed: 17-Apr-2021].

[7]L. Charder Electronic Co, “Body Composition,” *Height and Weight Scale, Portable Digital Scales*, 2020. [Online]. Available: https://www.chardermedical.com/innovation.htm. [Accessed: 17-Apr-2021].

[8] J. M. a. B. T. S Ekins, "In silico pharmacology for drug discovery: methods for virtual ligand screening and profiling," NCBI, 4 June 2007. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1978274/. [Accessed 23 April 2021].

[9] "Electronics Club," [Online]. Available: https://electronicsclub.info/impedance.htm. [Accessed 23 April 2021].

[10] Clem Asogwa, Assefa Teshome, Stephen F Collins, Daniel T.H. Lai, "A Circuit Model of Real Time Human Body Hydration," ResearchGate, October 2015. [Online]. Available: https://www.researchgate.net/publication/283048641_A_Circuit_Model_of_Real_Time_Human_Body_Hydration. [Accessed 23 April 2021].

[11] O. Jones, "Anatomical Planes," TeachMeAnatomy , 6 January 2018. [Online]. Available: https://teachmeanatomy.info/the-basics/anatomical-terminology/planes/. [Accessed 23 April 2021]

[12] "602030 mini Lipo Rechargeable Lithium Battery 300mAh 3.7V Bluetooth MP3 Wireless Card Audio Recorder Li-ion Cell Batteries," Aliexpress, [Online]. Available: https://www.aliexpress.com/item/1005001310236068.html?src=google&albch=shopping&acnt=708-803-3821&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&&albagn=888888&isSmbAutoCall=false&needSmbHouyi=false&albcp=7386. [Accessed 2 April 2021].

[13] iStock, [Online]. Available: https://www.istockphoto.com/illustrations/gender-symbol. [Accessed 23 April 2021].

[14] Wei Chen, "Body Composition Analysis by Using Bioelectrical Impedance in a Young Healthy Chinese Population: Methodological Considerations," 2017.

[15] Robert Ross, Luc Leger, Paul Martin, Roch Roy, "Sensitivity of bioelectrical impedance to detect changes in human body composition," the American Physiological Society, 1989.

[16] T. K. Bera, "Bioelectrical Impedance Methods for Noninvasive Health Monitoring: A Review," [Online]. Available: https://www.hindawi.com/journals/jme/2014/381251/. [Accessed 20 April 2021].

[17] [Online]. Available: https://www.healthline.com/health/sodium-blood. [Accessed 24 April 2021].

[18] “RN4871-V/RM118 - BLE MOD W/ANTENNA, 2.442MHZ, 0.1DBI,” *Newark*. [Online]. Available: https://canada.newark.com/microchip/rn4871-v-rm118/ble-mod-w-antenna-2-442mhz-0-1dbi/dp/01AC4946?s_kwcid=AL%218472%213%21507454857750%21%21%21u%21334507183893%21&mckv=_dc%7Cpcrid%7C507454857750%7Cplid%7C%7Ckword%7C%7Cmatch%7C%7Cslid%7C%7Cproduct%7C01AC4946%7Cpgrid%7C122092002120%7Cptaid%7Cpla-334507183. [Accessed: 25-Apr-2021].

[19] “Intel Pentium Dual Core Processor,” *Amazon.ca*. [Online]. Available: https://www.amazon.com/Intel-Pentium-Dual-Core-Processor-800MHz/dp/B0010TCK3A/ref=sr_1_19?_encoding=UTF8&c=ts&dchild=1&keywords=Computer+CPU+Processors&qid=1616791998&s=pc&sr=1-19&ts_id=229189. [Accessed: 24-Apr-2021].

[20] “MCP4822-E/P,” *DigiKey*. [Online]. Available: https://www.digikey.ca/en/products/detail/microchip-technology/MCP4822-E%2FP/951465?utm_adgroup=Data+Acquisition+-+Digital+to+Analog+Converters+%28DAC%29&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Integrated+Circuits+. [Accessed: 25-Apr-2021].

[21] “4.0US $ 41% OFF: 602030 mini Lipo Rechargeable Lithium Battery 300mAh 3.7V Bluetooth MP3 Wireless Card Audio Recorder Li ion Cell Batteries: Replacement Batteries: - AliExpress,” *aliexpress.com*. [Online]. Available: https://www.aliexpress.com/item/1005001310236068.html?src=google&albch=shopping&acnt=708-803-3821&isdl=y&slnk=&plac=&mtctp=&albbt=Google_7_shopping&aff_platform=google&aff_short_key=UneMJZVf&&albagn=888888&isSmbAutoCall=false&needSmbHouyi=false&albcp=7386. [Accessed: 25-Apr-2021].

[22] “Cortex-M4,” *Arm Developer*. [Online]. Available: https://developer.arm.com/ip-products/processors/cortex-m/cortex-m4. [Accessed: 18-Apr-2021].

[23] J.-L. Aufranc, “Samsung S3FBP5A Bio-Processor Targets Fitness Tracking Wearables - CNX Software,” *CNX Software - Embedded Systems News*, 09-Jun-2017. [Online]. Available: https://www.cnx-software.com/2015/12/30/samsung-s3fbp5a-bio-processor-targets-fitness-tracking-wearables/. [Accessed: 18-Apr-2021].

[24] “Apple Watch Series 5,” *GSMArena*. [Online]. Available: https://www.gsmarena.com/apple_watch_series_5-9859.php. [Accessed: 18-Apr-2021].