this watch could save your life.

WEARABLE SALINITY SENSOR FOR SCREENING CYSTIC FIBROSIS AND PROTECTING ATHLETES FROM HYPONATREMIA

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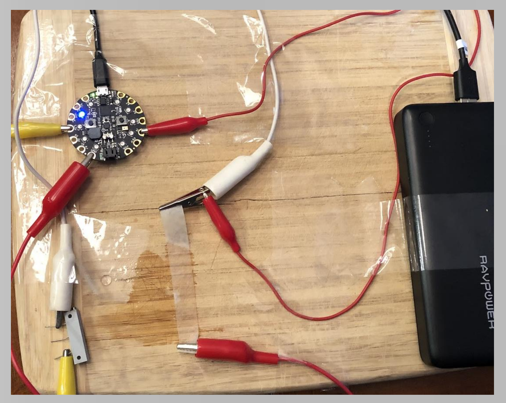
Abstract

In the span of 10 years, 7,233 Americans died of heat related causes. Meanwhile, 70,000 people worldwide suffer from cystic fibrosis, the bulk of which go undiagnosed. The current procedure for screening CF is costly and inefficient. The engineers created a device that solves these problems: a wearable salinity sensor to pre-screen people for CF and to ensure that athletes maintain adequate electrolyte levels. Using an Arduino Adafruit Circuit Playground with an A/D converter, a potentiometer, and wiring, the engineers created a functioning wearable ohmmeter device to measure sweat salinity. They tested it with several salt solutions that mimic the electrolyte content of human sweat (0.05%, 0.1%, 0.15%, and 0.2%) as well as with distilled water as a control. The device, nicknamed CAEMP (Compact Arduino Electrolyte Measurement Prototype), found a negative correlation between the percentage of salt in a solution and the solution's resistance. CAEMP is able to provide real time feedback when provided with a sweat sample, and is able to monitor a wide range of electrolycity data. CAEMP also displayed useful degrees of precision and accuracy throughout testing, providing data sets with an average standard deviation of 31.2813 kΩ. For a device that can distinguish over a hundred 10 kΩ neopixels, this ensures clearly different and accurate displays for differing data points. CAEMP can easily recognize the required level of variation and finer, making it an effective and potentially life-saving tool.



Introduction

Cystic fibrosis is a genetic disorder, passed down through a recessive gene. The disorder causes sweat, mucus, and digestive fluids to become viscous, clogging passageways in the lungs, pancreas, and other parts of the body. Newborns are screened for cystic fibrosis, a more recently implemented procedure, but some cases have a late onset or delayed symptoms. Additionally, people born before screenings became commonplace stand at risk of developing potentially fatal late onset symptoms of cystic fibrosis. Some symptoms and complications include: prolonged coughing and wheezing, constipation, greasy and vile smelling feces, rectal prolapse, bronchiectasis (damage to the airways), chronic respiratory infections, or even complete respiratory failure, which causes death. Other complications may include difficulty absorbing nutrients, diabetes, infertility, osteoporosis, and electrolyte imbalances. The key diagnostic tool is a sweat test, because the disorder leads to an increased concentration of salt in sweat. Currently there is a standardized process in which late diagnostic cystic fibrosis is detected, but the process is long and prohibitively expensive.

Hyponatremia is a heat and exercise related condition. It is caused by the dearth of electrolytes present in the body, and diagnosable by a similar lack measured in sweat. Hyponatremia is common in athletes, as they sweat out much of their electrolytes and only consume water, which does not replenish them. While sports drinks and powders can remedy this, it is impossible to tell when the onset of hyponatremia could occur. Symptoms of hyponatremia include nausea, vomiting, headache, drowsiness, seizures, coma, and potentially death.

Research Question:
Can we build and program a compact and cost effective device that measures the amount electrolytes found in sweat to diagnose cystic fibrosis and protect from hyponatremia?

Hypothesis:
We expect that higher levels of electrolytes will result and greater conductivity, and therefore less resistance. This is because salts are made up of ionic bonds that, when dissolved in water dissociate and become charged particles, conducting electricity. Accordingly, we expect that our device will be able to determine differences in salinity through measuring resistance, and therefore diagnose cystic fibrosis and recognize hyponatremia.

Engineering Goal:
We want to build a device that will cheaply and effectively measure sweat electrolyte content. it will measure the electrolytes on the skin in order to serve as a diagnosis for late onset cystic fibrosis and warn of hyponatremia. We will aim to create a program that gives immediate feedback of the data measured and is readable to the user. The device will utilize electrodes to take the measurements, and use an Arduino board to display the data with neopixels.

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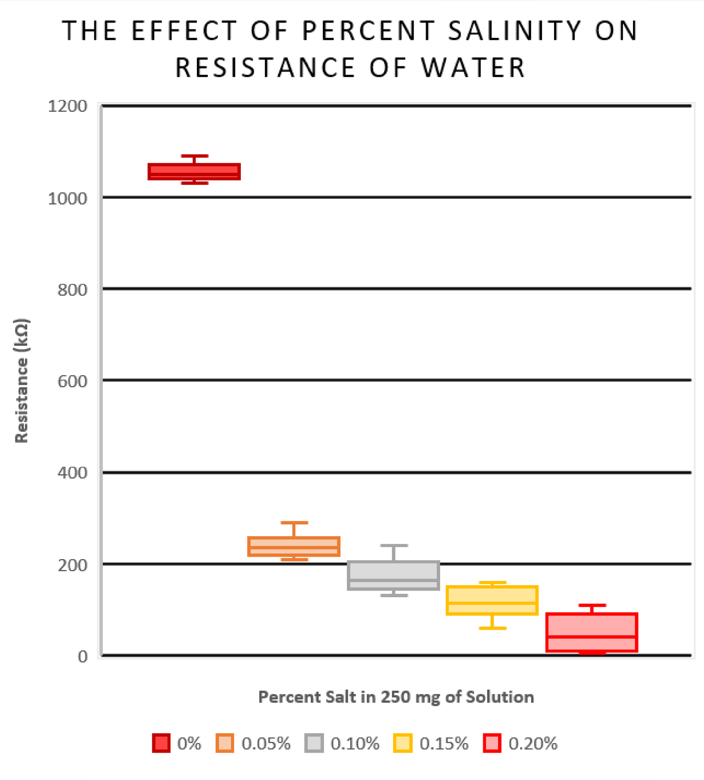
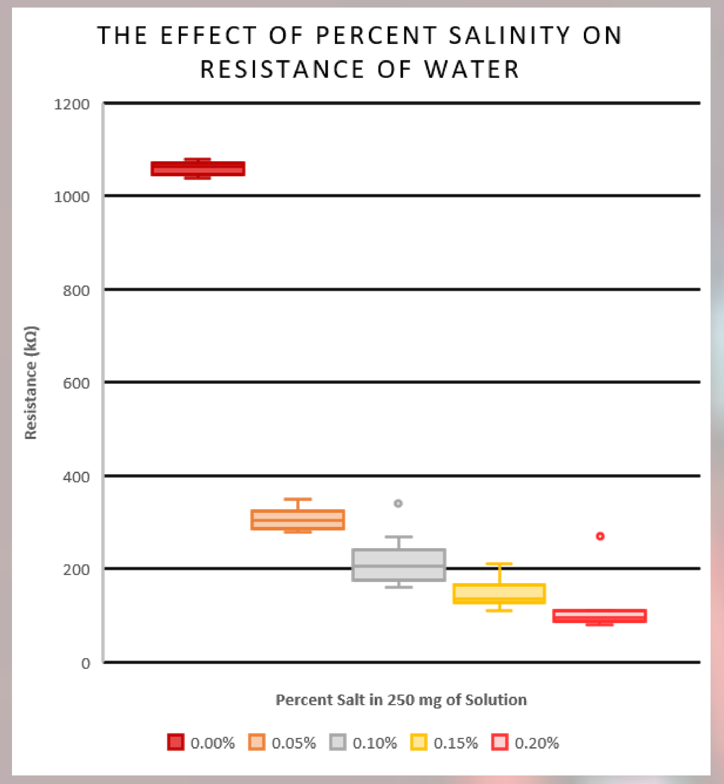
Results

Final Prototype Data

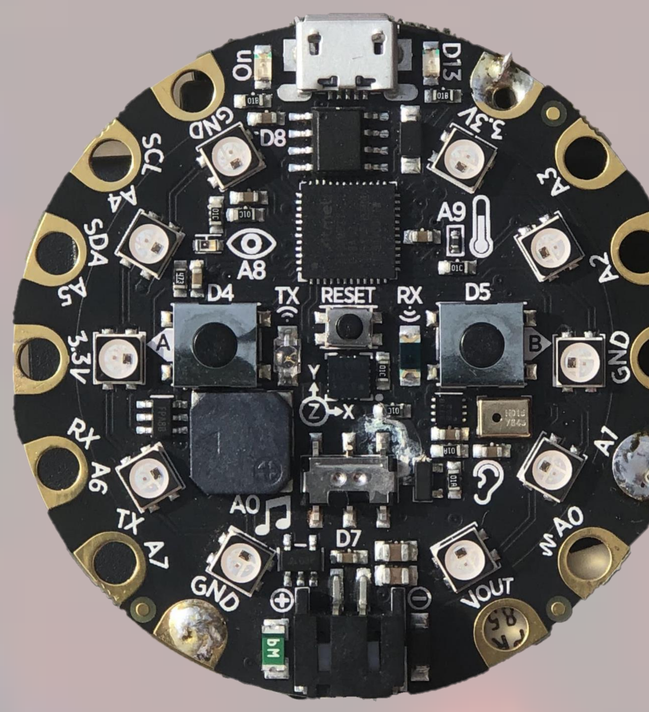
Trial #	0%	0.05%	0.10%	0.15%	0.20%
1	1050	280	190	150	90
2	1070	210	220	150	90
3	1060	210	240	120	110
4	1040	220	170	110	70
5	1040	240	150	160	50
6	1040	250	130	90	30
7	1030	230	200	90	10
8	1090	240	150	120	10
9	1070	290	160	60	5
10	1050	220	130	90	5
σ =	18.37873	27.66867	37.47592	32.38655	40.49691
μ of σ =	31.28136				

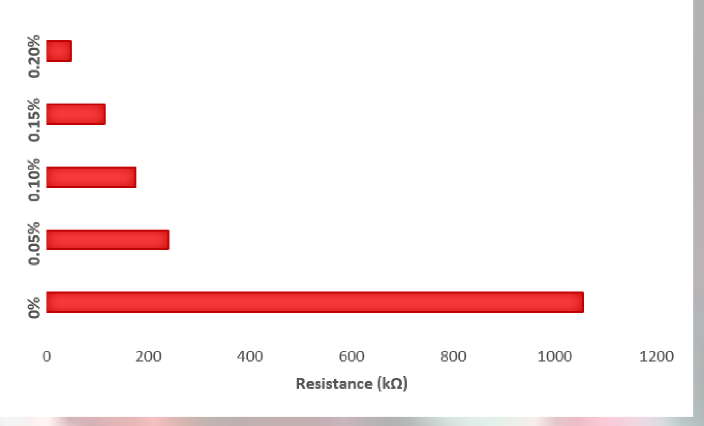




Experimental Prototype Data

Trial #	0%	0.05%	0.10%	0.15%	0.20%
1	1080	340	230	140	100
2	1080	350	340	130	90
3	1070	280	230	210	100
4	1050	320	200	180	80
5	1070	280	180	130	110
6	1060	290	160	160	110
7	1040	320	210	110	80
8	1070	300	160	120	270
9	1060	310	270	130	90
10	1040	290	180	140	90
σ =	14.7573	24.40401	55.61774	30.2765	56.52925
μ of σ =	36.31696				





Procedure for assembling CAEMP (Compact Arduino Electrolyte Measuring Prototype):

Set potentiometer to equal 1 MΩ.
Connect one end of green alligator clip to one lead of the potentiometer and the other end to GND (ground) on Arduino board.
Connect one end of red alligator clip to the other lead of the potentiometer and leave the other end open.
Connect one end of the yellow alligator clip to 3.3V on the Arduino board and leave the other end open.
Connect one end of the white alligator clip to A1 on the Arduino board and the other end to the same lead on the potentiometer as the red clip.
Plug in power cord to portable charger battery and wait for LED under "On" to turn green.

Procedure for determining device successfulness:

Take 6 clean glass cups, and label each with percent salinity (0%, .05%, .1%, .15%, .2%, and 1%) using sharpie and tape.
Add 250 mg of distilled water to the 1% cup, and then add 2.5 mg of salt.
Use stirring rod and gently stir salt and water together for 2 minutes, or until salt is completely dissolved.
Add 250 mg of distilled water to the 0% cup.
Add 237.5 mg of distilled water and 12.5 mg of 1% solution to the .05% cup.
Add 225 mg of distilled water and 25 mg of 1% solution to the .1% cup.
Add 212.5 mg of distilled water and 37.5 mg of 1% solution to the .15% cup.
Add 200 mg of distilled water and 50 mg of 1% solution to the .2% cup.
Mix all solutions, washing the stirring rod with distilled water intermittently.
Clip the open ends of the yellow and red alligator clips vertically to the far edges of the dry coffee filter paper.
Using the pipette, evenly coat the filter paper with 1 mL of solution, being sure to coat the entire strip.
Watch neopixels on the circuit board for a blue light, followed by a red light.
Record numbers in a data table.*
Take away wet strip and dry alligator clips with paper towel.
Repeat steps 10-14 for the 0%, .05%, .1%, .15%, and .2% solutions, and for all repeated trials.
Clean up all materials used and turn off CAEMP.

*Reading Outputs on Circuit Board: There are ten neopixels on the Adafruit Circuit Playground, each representing numbers 0 through 9. The pixels correspond to numbers in order, going counter-clockwise. Comparing the board to a clock, the power cable (where it says "D13" and "On") should be connected at 12 o'clock, and "3.3V" should be at 9 o'clock. The neopixel immediately left of the "On" represents "0". The neopixel directly following, in between A4 and A5, represents "1", and so on. When connected to a power source, and if circuit is continuous, a blue light will flash on the board. Immediately afterward, one will neopixel will light up red. The blue light represents the number in the hundreds place, and the red the tens place. So if a blue light flashes at "3", following a red light at "9", it is measuring 390 ohms.

Methodology

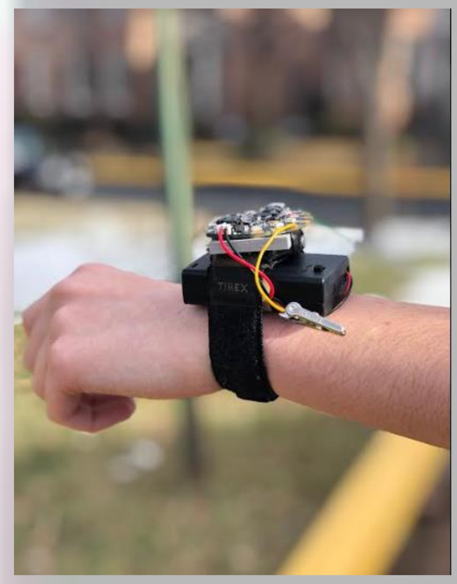
Prototype Materials: Arduino Adafruit Circuit Playground, alligator clips, potentiometer, portable charger battery, wooden bread board.
Experimentation Materials: C++ program, standard multimeter, computer, 90 kiloohm and 320 kiloohm resistors, 4 insulated alligator clips (yellow, green, red, and white), 4 in. by 1/2 in. strips of coffee filter paper, scale, 2.5 mg pure salt, 1237.5 mg distilled water, 6 glass cups, micro pipette, scotch tape, sharpie, stirring rod, paper towels.

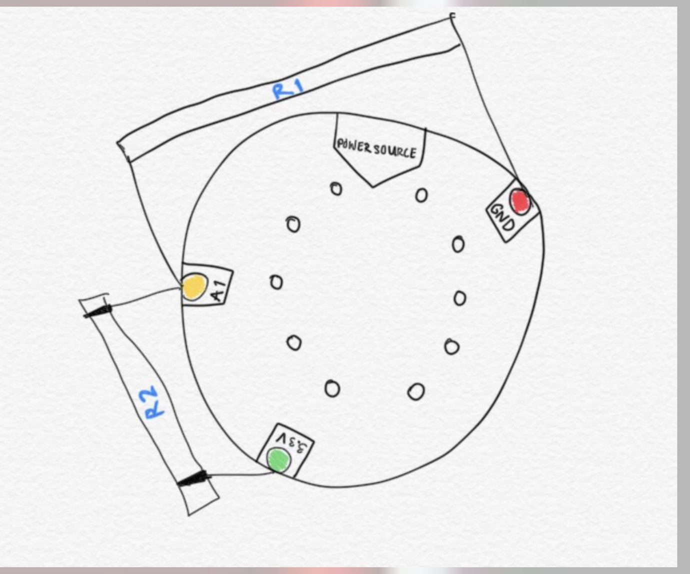
The device was built to measure resistance across a span subjected to a varied resistor, essentially creating an ohmmeter out of an A/D converter. A program in C++ was written to accomplish this in conjunction with the device's hardware. The program is as follows:

```
#include
#include

/*
Ohm meter based on 1M Ohm
reistor and a resistor under test.
Vs applies voltage across the two
resistors.  V1 measures across
the 1MOhm
resistor.  Calculations the
determine R2 (device under test)

*/

int sensorPin = A1; // select the
input pin for the potentiometer
int SV1 = 0;  // variable to store
the value coming from the sensor
int SV2 = 0;  // variable to store
the value coming from the sensor
int SV3 = 0;  // variable to store
the value coming from the sensor
int SV4 = 0;  // variable to store
the value coming from the sensor
int SV5 = 0;  // variable to store
the value coming from the sensor
int lednum1;
int lednum2;
double I1=0;
double R2=1.072e6;
double R1=0;
double V1=0;
double Vs=3.289;

void setup() {
CircuitPlayground.begin();
//CircuitPlayground.setPixelColor
(5, 0,0,255);
CircuitPlayground.clearPixels();

}

void loop() {
CircuitPlayground.clearPixels();
delay(100);
// read the value from the sensor:
SV1 = analogRead(sensorPin);  //
Average Five Samples of Voltage
delay(200);
SV2 = analogRead(sensorPin);
delay(200);
SV3 = analogRead(sensorPin);
delay(200);
SV4 = analogRead(sensorPin);
delay(200);
SV5 = analogRead(sensorPin);
V1=Vs*(SV1+SV2+SV3+SV4+SV
5)/(5*1023);  // Voltage

delay(200);
SV1 =
analogRead(sensorPin); //
Average Five Samples of
Voltage
delay(200);
SV2 =
analogRead(sensorPin);
delay(200);
SV3 =
analogRead(sensorPin);
delay(200);
SV4 =
analogRead(sensorPin);
delay(200);
SV5 =
analogRead(sensorPin);


V1=Vs*(SV1+SV2+SV3+SV4
+SV5)/(5*1023);  // Voltage

delay(200);
SV1 =
analogRead(sensorPin); //
Average Five Samples of
Voltage
delay(200);
SV2 =
analogRead(sensorPin);
delay(200);
SV3 =
analogRead(sensorPin);
delay(200);
SV4 =
analogRead(sensorPin);
delay(200);
SV5 =
analogRead(sensorPin);


V1=(Vs*(SV1+SV2+SV3+SV4
+SV5)/(5*1023)+V1)/2;
I1=V1/R2;
R1=(Vs-V1)/I1;

lednum1=floor(R1/100000);
Serial.println(R1);
Serial.println(lednum1);
lednum2=round(10*(R1/1000
00-lednum1));
Serial.println(lednum2);
//Serial.println(lednum2);

CircuitPlayground.setPixelCol
or(lednum1, 0, 0, 255) ;
delay(500);
CircuitPlayground.setPixelCol
or(lednum2, 255, 0, 0) ;
delay(500);
}
```

Conclusion

CAEMP is capable of providing the precision and accuracy necessary to effectively screen for cystic fibrosis and monitor the onset of hyponatremia. Simply looking at the numbers, the average standard deviation of our data sets was 31.2813 kilo ohms. Our device measures in ten kΩ increments, lighting up different lights to indicate values. This means that any data point is likely to be within three lights of the actual value to either side. Note that this variability is only present while measuring solutions, when a resistor is measured the results are virtually always accurate to the light. In order to effectively screen for cystic fibrosis, our device would need to be able to determine the difference between the average human sweat, a 0.11% salt solution, and a solution three times that electrolyte content. It would also need to be able to determine a gradual downward change in electrolyte content. After the programming, prototyping, and experimentation processes, CAEMP has proven to consistently measure and display far more precise data than required, pertaining to the resistance of different solutions with varying salinity. It is also capable of displaying data in real time. Despite these capabilities, CAEMP is vulnerable to some limited error. As previously stated, data points when measuring solutions had an average standard deviation of 31.2813 kΩ. This error derives from the following sources: regularity of sweat patch size, the placement of the alligator clips, accuracy of solution measurement, evaporation, and absorption of solutions into the sweat patch. Despite this error, CAEMP still manages to provide accurate and precise data. This justifies its use in the medical field in identifying patients with abnormally high salinity in their sweat, and as a useful and life-saving tool for preventing conditions related to electrolyte deficiency.





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