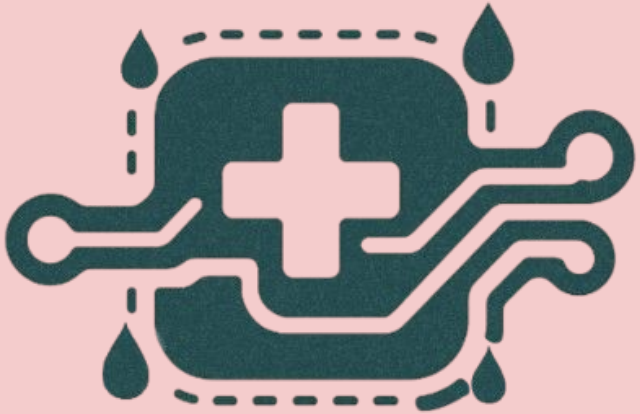
SmartSweat

Project 11: Wearable Sweat Chemical Analyte Patch



Our Team

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Outline:

1. Problem
2. Proposed Solution
3. Housing Trade Study
4. Electronics Trade Study
5. Data Collection Methods
6. Device Trade Study
7. Concluding Remarks

Problem:

According to an article by the American Chemical Society:

"Sports physiology will likely benefit from a technology able to account for **high-resolution temporal lactate changes according to the intensity of the physical activity**, rather than discrete information from centralized lab-based analysis."

Problem:

What:

- Lactate sensors on the market are usually **invasive** and require **lab analysis**
- There is a large market gap for non-invasive, real time lactate sensors available to the general public

Who:

- Main **users** will be athletes and also the average consumer looking to track their health and daily activities
- Main **stakeholder** will be Dr. Amir Sahjadi, who is looking for a device unique and novel enough to publish and hopefully patent

Problem:

Why**:**

- This market gap exists due to the difficulty in isolating and detecting specific chemicals in sweat (such as lactate or sodium)

How**:**

- Our team is proposing a dual electrochemical lactate and sodium sensor working in combination with an mobile device app to provide real-time lactate and sodium analysis on the user's sweat.

Prototype Sketch:

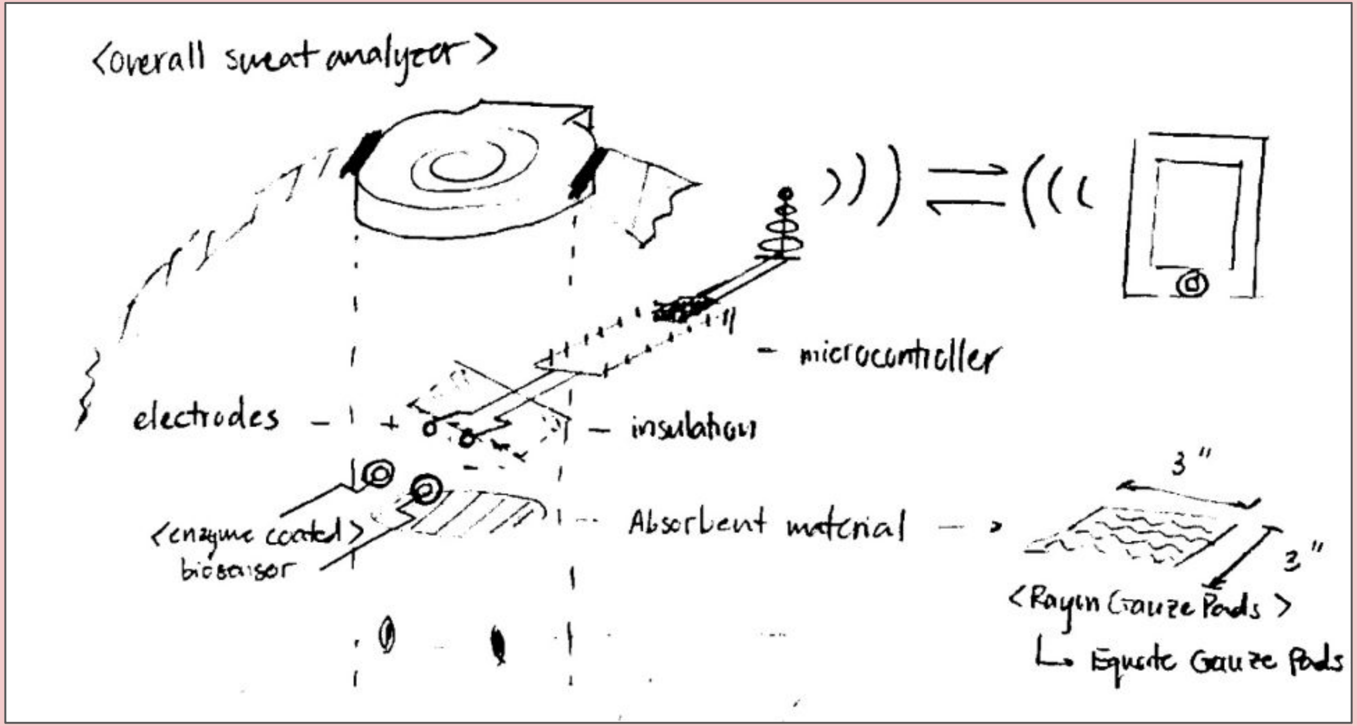
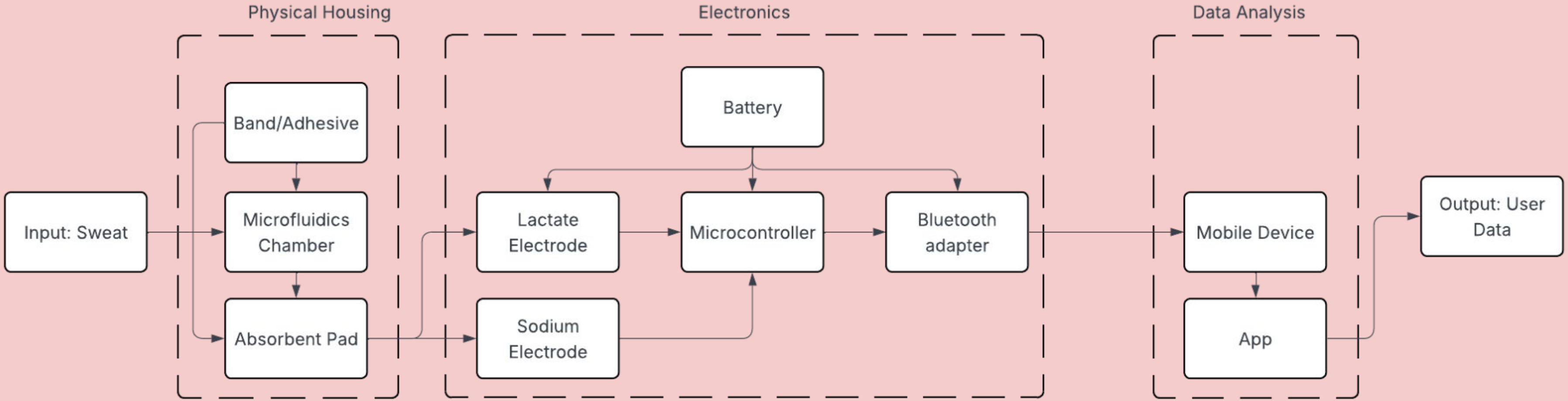


Fig 1. - Prototype Rough Sketch

System Overview:



Needs to Requirements Table (p1) :

1 - Physical Housing	
2 - Sensors	
3 - Data Processing	
4 - Miscellaneous	

Number	Need / Objectives (N)	Requirement (R)	Means of Effectiveness
1.1	The device needs to be non-invasive	The device shall not penetrate the skin layer (draw blood)	Pass/Fail
1.2	The device should be reusable	The device electronic components shall be reusable for multiple tests	as many runs as possible
1.3	The device should not impede the user's activities	The device shall be compact enough to fit on an appendage	smallest volume as possible (m^3)
1.4		The device shall not exceed a weight of 5 pounds	as light as possible (g)
1.5		The device shall be securely fastened to an area of the user's body	

Needs to Requirements Table (p2):

1 - Physical Housing	
2 - Sensors	
3 - Data Processing	
4 - Miscellaneous	

Number	Need / Objectives (N)	Requirement (R)	Means of Effectiveness
2.1	The device should detect **sodium** and **lactate** (dual) concentrations in sweat	The device shall use electrodes to electrochemically detect electric sodium potential in sweat	Detect within range of 200 - 2000 mg/L
2.2		The device shall use electrodes in conjunction with an enzyme coating to detect electric potential in sweat	Detect within range of 5 - 40 mmol/L
2.3	The device should function independently	The device shall be powered with a battery that can power all components for 24 hours	as long a runtime as possible (hrs)
2.4		The device shall transmit biodata to a mobile device using a bluetooth transmitter	Pass/Fail
3.1	the data needs to be analyzed from a different device	A separate mobile device shall receive the transmitted bio-data using a bluetooth transmitter	Pass/Fail
3.2		The app shall present the data on a scatterplot graph	Pass/Fail
4.1	The device must fill a unique gap in the market	*(Fulfilled by 2.1, 2.2, and 3.1)*	
4.2	The device must be patentable		

Subsystems Breakdown:

Subsystem:	Form:	Function:	Requirements:
Physical Housing	Band / Adhesive	Secure device to user body	R1.3, R1.4, R.1.5
	Absorbent Patch	Accumulate sweat in concentrated area	R2.1 R2.2
	Microfluidics Chamber		
Electronics	Battery	Power all device electronic components	R2.1 R2.2, R2.3, R2.4
	Sodium Electrodes	Detect sweat sodium concentrations	R2.1
	Lactate Electrodes	Detect sweat lactate concentrations	R2.2, R4.1, R4.2
	Bluetooth Adapter	Transmit biodata to mobile device	R2.4
	Microcontroller	Control all digital processes from device	R2.1 R2.2, R2.4
Data Analysis	Mobile Device	Receive bluetooth transmissions from microcontroller	R3.1
	App	Perform curve fitting and present to user	R3.2

Housing: Design Options

	Pros	Cons
Patch	• Low Profile • No mechanical parts • Disposable • Good skin contact	• Adhesive may irritate skin • Not reusable • May fall off with sweat or motion • Difficult to reposition
Band	• Reusable • Can reposition • Adjustable fit	• Consistent Tension • May slip during heavy exercise • sweat flow may vary with with movement/pressure

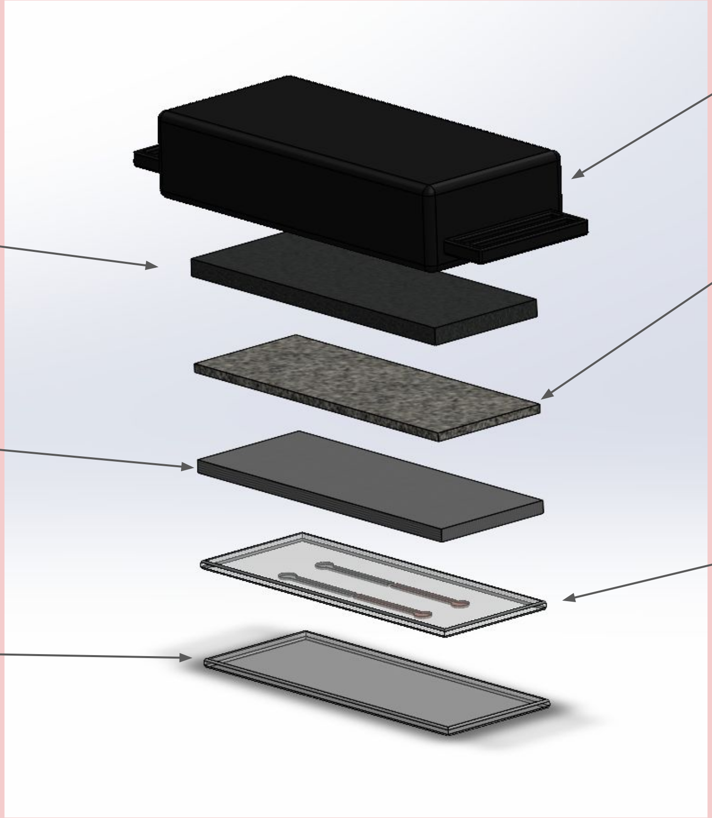
Housing: Sweat Collection

	Pro	Cons
Microfluidics	• Continuous flow enables real time sensing • Compact and low power • Compatible with Lactate and Na^+	• Requires a sufficient sweat rate • Can dry out at rest • Precise Fabrication
Absorbent Pad/ Hydrogel Wicking	• Lost cost, simple assembly • Works at low sweat rates • Comfortable and flexible on skin	• Saturate over time • Hard to calibrate volume • Evaporation if exposed
Sweat-Permeable Membrane	• Stable Readings • Protects electrodes from debris and salts	• Slow response • Requires thin, uniform membrane bonding

Housing: Sweat Stimulation

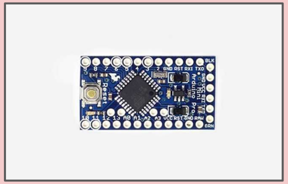
	Pros	Cons
Iontophoretic Stimulation	• Works at rest • Produces controlled, repeatable sweat volume • Used successfully in clinical chloride tests	• Requires power control circuitry • Possible Mild Skin Irritation
Thermal Stimulation	• Simple integration with heater/thermistor • Can be toggled to regulate sweat rate	• Uses a lot of homework • Heat may affect sensors • Uneven sweat induction across users

Rough Model



Case
Battery
Bluetooth Transmitter
Lactate/Sodium Sensor
Electrodes
Sweat Collection

Electrical Proposal:



Board	Clock Speed	Size	Pins	Price
Arduino Uno	ATmega328P, 16 MHz	~68.6 × 53.4 mm	14 digital I/O (6 PWM), 6 analog inputs	$25-30
Arduino Nano	ATmega328 (classic) 16 MHz	~45 × 18 mm	~14 digital I/O, ~8 analog inputs	$18-20
Arduino Pro Mini	ATmega328 (or ATmega168) 16 MHz (5 V version)	~18 × 33 mm	14 digital I/O, 6 analog (common)	$10-12

Recommendation: Arduino Nano
Pros: lightweight and compact form factor, good for prototyping because of more pins, some models have built in Bluetooth
Cons: more expensive than the pro mini

Electrode Trade Study

A	B	C	D	E	F	G
	Carbon/Graphene	**Gold/Platinum**	**Ag/AgCl**	**ISE (membrane)**	**Conductivity (IDE)**	**LOx+Mediator**
Carbon/Graphene	0.5	0	0.5	0.5	0.5	0.5
Reason	—	Cheaper & flexible	Compact, wearable	Moderate selectivity	Simple, robust	Sensitive, selective
Gold/Platinum	1	0.5	0.5	0.5	0.5	0.5
Reason	Stable, low noise	—	Compact, wearable	Moderate selectivity	Simple, robust	Sensitive, selective
Ag/AgCl	0.5	0.5	0.5	0.5	0.5	0.5
Reason	Compact, wearable	Compact, wearable	—	High selectivity	Simple, robust	Sensitive, selective
ISE (membrane)	0.5	0.5	0.5	0.5	1	0.5
Reason	High selectivity	High selectivity	High selectivity	—	Easy to implement	Sensitive, selective
Conductivity (IDE)	0.5	0.5	0.5	0	0.5	0.5
Reason	Robust, simple	Robust, simple	Robust, simple	Less selective	—	Sensitive, selective
LOx+Mediator	0.5	0.5	0.5	0.5	0.5	0.5
Reason	Selective, sensitive	Selective, sensitive	Selective, sensitive	Selective, sensitive	Selective, sensitive	—

1- row objective is preferred over column objective   0- column objective is preferred over row objective   0.5- equally valued

Lactaid / Sodium Sensors:

Lactate Sensor (amperometric, enzyme-based):

- A technique that involves measuring an electric current (amperes) to determine a result
- **Screen-printed carbon or gold electrode** modified with **Lactate Oxidase (LOx)** + mediator (e.g., Prussian Blue).
- 3-electrode configuration: **Working (WE)** / **Counter (CE)** / **Reference (Ag/AgCl)**.
- Measures oxidation current proportional to lactate concentration (5–40 mM range).

Sodium Sensor (potentiometric):

- a method that measures a system's electrical potential to determine the concentration of a substance.
- Na^+ Ion-Selective Electrode (ISE) with Ag/AgCl reference.
- Measures potential difference that follows **Nernst equation** (logarithmic response vs $[Na^+]$).
- Alternative: **Interdigitated conductivity electrodes** for total ionic strength (simpler, non-selective).

Sodium Sensor

1. Electrode Substrate
   https://www.msesupplies.com/products/basi-screen-printed-electrode-ac1-1mm-gold-working-silver-silver-chloride-reference
2. **Coat with sodium membrane**
   a. Sodium ionophore x
      i. https://www.sigmaaldrich.com/US/en/product/sial/71747?utm_source=chatgpt.com
   b.

Lactate Sensor

1. **Electrode Substrate**
   https://www.msesupplies.com/products/basi-screen-printed-electrode-ac1-1mm-gold-working-silver-silver-chloride-reference
2. Lactate Oxidase
   a. https://www.sigmaaldrich.com/US/en/product/sigma/l9795?srsltid=AfmBOoomKFENRSIFpHgLaIopV9uk2IbQ4P9zmzhJ6mY5h3wK5lBQgr6sHQ0
   b.
3. Prussion Blue catalytic layer under enzyme
4.

Testing Methods:

1. Sensors Test
    a. Synthetic Sweat with known lactate/sodium levels
    b. Use lactate test kit that changes color depending on lactate levels
    c. Compare to sensors readings
2. On Body Test
    a. Place sensor on chest
    b. Ride assault bike at 60 rpm for 5 minutes
    c. Test data collection and transmission to app continuously pre, during and post exercise

Data Collection & Calibration

Lactate (Amperometric):

- Use **chronoamperometry** (An electrochemical method where a sudden potential step is applied, and the resulting current is measured over time) at fixed potential; sample **1–10 Hz**; current → [Lactate].
- Calibrate with 3–5 standards (5–40 mM).

Sodium (Potentiometric):

- Measure potential vs Ag/AgCl (silver/silver chloride); sample **0.1–1 Hz**.
- Calibrate with NaCl solutions (10–150 mM); log-fit for Nernst slope.

- **Temperature compensation:** add thermistor near electrodes; correct readings.
  Motion filtering: use onboard **IMU** to reject artefacts during movement.
  Bluetooth output: stream processed values to phone/dashboard app.

Data Analysis

- Digital signal transmitted through bluetooth into mobile device
- Convert the raw data into insight with equations for Sodium and Lactate
- Interpret results

Na < 40 mM	Low sodium	Hydrated
Na > 79 mM	High sodium loss	Risk of Dehydration
Lactate < 2mM	Resting	
Lactate 4-10 mM	Intense Exercise	

Device Trade Study

Pairwise Comparison Chart

1- row objective is preferred over column objective
0- column objective is preferred over row objective
0.5- equally valued

	Design Objectives	Non-invasive Data Collection	Real-time Sensing	Mobile-App data analysis	Wireless data Transmission	Sodium + Lactate dual detection	Wearable physical device	Feasible	Easy to use	Low cost	Comfortable	Novel	Reusable	Independently	Compact	Lightweight	Score
1	Non-invasive Data Collection		1	1	1	0	0	1	1	1	1	1	1	1	1	1	12
2	Real-time Sensing	0		0.5	0	0	0.5	1	1	1	1	1	1	1	1	1	10
3	Mobile-App data analysis	0	0.5		0.5	0	0	1	1	1	1	1	1	1	1	1	10
4	Wireless data Transmission	0	0.5	0.5		0	0.5	1	1	1	1	1	1	1	1	1	10.5
5	Sodium + Lactate dual detection	1	1	1	1		1	1	1	1	1	1	1	1	1	1	14
6	Wearable physical device	0	0	0	0	0		1	1	0.5	1	1	1	1	1	1	8.5
7	Feasible	0	0	0.5	0	0	0.5		1	0.5	1	0.5	1	1	1	1	8
8	Easy to use	0	0	0	0	0	0	0		0	1	0.5	0.5	0	1	1	4
9	Low cost	0	0	0.5	0	0	0.5	0.5	1		1	0.5	1	0.5	1	1	7.5
10	Comfortable	0	0	0	0	0	0	0	0	0		0	0	0	0.5	0.5	1
11	Novel	0	0	0	0	0	0	0.5	1	0	1		1	0	1	1	5.5
12	Reusable	0	0	0	0	0	0	0	0.5	0.5	1	0.5		0.5	1	1	5
13	Independently powered	0	0	0.5	0	0	0	0.5	1	0.5	1	0.5	0.5		1	1	6.5
14	compact	0	0	0	0	0	0	0	0	0	0.5	0	0	0		0.5	1
15	lightweight	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5		1

Device Trade Study

Weight Scale	
1	Far below average, poor
2	Below Average
3	Average
4	Above Average
5	Far above Average

Concepts: Physical

Concept A: Non slip band you can strap anywhere (Sports band), like a watch

Concept B: An adhesive lightweight patch (sticks on)

Concepts - Chemical

Concept D: Detect Lactate

Concept E: Detect Sodium

Concept F: Detect Sodium + Lactate

			Concept A		Concept B	
		Weight factor	Score	Value	Score	Value
1	Non-invasive Data Collection	5	5	25	5	25
2	Real-time Sensing	4	5	20	5	20
3	Mobile-App data analysis	4	5	20	5	20
4	Wireless data Transmission	3	5	15	5	15
5	Sodium + Lactate dual detection	5	5	25	5	25
6	Wearable physical device	4	5	20	4	16
7	Feasible	4	5	20	3	12
8	Easy to use	2	5	10	3	6
9	Low cost	3	5	15	5	15
10	Comfortable	2	5	10	5	10
11	Novel	2	3	6	5	10
12	Reusable	2	4	8	4	8
13	Independently powered	3	5	15	5	15
14	compact	1	4	4	5	5
15	lightweight	1	4	4	5	5
	SUM			217		207

	Concept D		Concept E		Concept F	
Weight factor	Score	Value	Score	Value	Score	Value
5	5	25	5	25	5	25
4	5	20	5	20	5	20
4	5	20	5	20	5	20
3	5	15	5	15	5	15
5	5	25	5	25	5	25
4	5	20	5	20	5	20
4	2	8	5	20	5	20
2	5	10	5	10	5	10
3	3	9	5	15	3	9
2	5	10	5	10	5	10
2	5	10	0	0	5	10
2	5	10	5	10	5	10
3	5	15	5	15	5	15
1	5	5	5	5	5	5
1	5	5	5	5	5	5
SUM		207		215		219

Project Timeline:

When?

					Quarter 1										Quarter 2								
#	Tasks	Point	Completion		W1	W2	W3	W4	W5	**W6**	W7	W8	W9	W10	W1	W2	W3	W5	W6	W7	W8	W9	W10
	Wood Structure Assignment																						
1.1	Research																						
1.1	Purchasing																						
1.1	Overall Build																						
1.1	Electrical build / assembly	Luke / Tanya																					
1.1	Housing build / assembly	Auggie																					
1.1	Live tests	Eileen																					
2.1	Refining the Design																						
2.2	Marketing / Patent																						

Q&A