Team B1: A Portable, Affordable Cardiopulmonary Exercise Device

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Motivation

Standard CPET

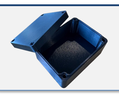
- **Large, bulky**, and **non-transportable**
- Only available in the clinic
- Most similar portable device is nearly **$6000**
- Following the pandemic, the **respiratory care device market** is estimated to be worth **$31.8 billion** by 2038

Our goal is to create a **portable**, **affordable** device to measure cardiopulmonary health factors as **accurately** as possible

Methods

Prototype Design

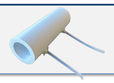
Tested **break-edge** design to prevent **air loss**



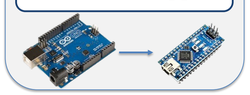
Used **L-shape** to facilitate holding and minimizing **empty space**

Minimized impact of **turbulence** in air flow via internal positioning

Designed a **spirometer** using an **asymmetrical cylinder** and a **differential pressure sensor**



Utilized **Arduino Nano** to connect **sensors** to **app**



Data Analysis for User Interface

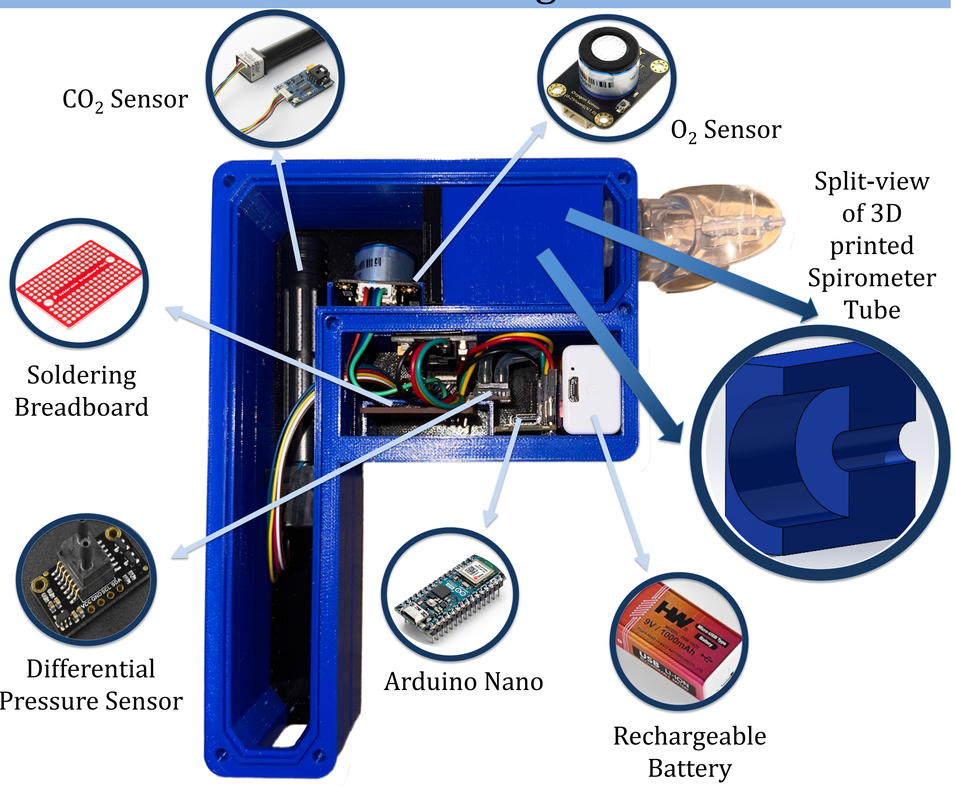
The device collects **O_2** & **CO_2 concentration**, and **pressure** at two points.

$$mF = \sqrt{\frac{2\rho P}{\left(1/A_2^2\right) - \left(1/A_1^2\right)}} \rightarrow VF = \frac{mF}{\rho} \rightarrow V = VF * dt + V$$

$$V_T * RR = VE(L/min) \rightarrow \begin{matrix} VO_2 = (O_{2_{air}} - O_{2_{raw}}) * \mathrm{VE} \\ VCO_2 = (CO_{2_{air}} - CO_{2_{raw}}) * \mathrm{VE} \end{matrix} \rightarrow RER = \frac{VO_2}{VCO_2}$$

$$RER > 1.0 \rightarrow MVO_2 \rightarrow \begin{matrix} M: PMVO_2 = \mathrm{w} * (50.72 - (.372 * \mathrm{a}))/1000 \\ F: PMVO_2 = ((\mathrm{w} * 42.8) * (22.78 - .17 * \mathrm{a}))/1000 \end{matrix}$$

Final Design



Health Outcomes

Table 1. Fitness Outcomes

Actual Max VO_2/Predicted Max VO_2 (%)	Fitness Indicator
>120%	Elevated
80-119%	Normal
60-79%	Mildly Impaired
40-59%	Moderately Impaired
<40%	Severely Impaired

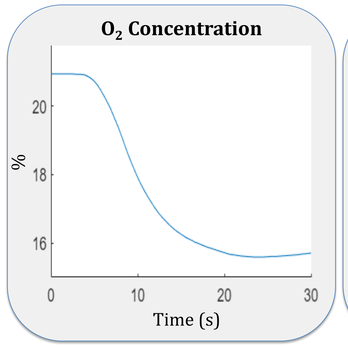
Table 2. Telemedicine Outcomes

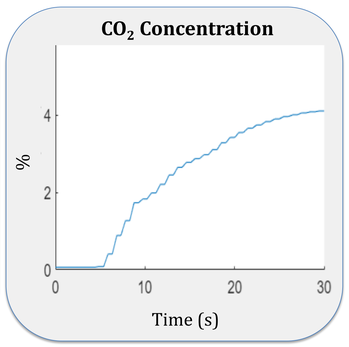
Evidence	Health Indicator
Max VO_2 <80% of predicted Max VO_2 Max VE <85% predicted Max VE RER < 1.10 (or 1.05, if using treadmill)	Suboptimal Test
Max VE ≥ 85% of predicted Max VE	Ventilatory Limitation
Max V_T < (2 x Baseline V_T)	Abnormal Ventilatory Response (Potential Lung Disease)

Bioethical Implications

- **Equality** in **research**; allows for cardiopulmonary studies in areas without access to clinical CPET tests
- More **convenient** for **athletes** and **patients** to track cardiopulmonary changes
- Requires **protections** to prevent health information from being obtained and **misused**

Results





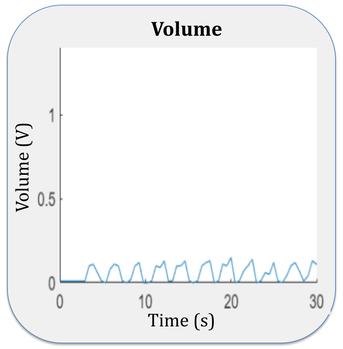


Figure 1-3. Graphical Outputs in App

Table 3. Variable Outputs in App

Value	Baseline	Post-Exercise
VO_2 (L/min)	111.5	379.4
VCO_2 (L/min)	3.282	15.2
V_T (L)	0.08	0.16
RER	0.6542	.8904
RR (breaths/min)	14	22

Conclusions

- Adjusted CAD models to account for 3D printing tolerances
- Learned about medical device testing implementation
- Integrated multiple sensors in parallel using I2C technology
- Demonstrated proof of concept, needing improvement with higher sensor accuracy

Future Work

- Translate MATLAB app into **mobile app**
- Enable **Bluetooth** capabilities with Arduino
- **Higher accuracy** for medical conclusions
- Improve case **ergonomics**, including weight distribution

References

[1] Cassady, Steven UMSOM. CPET Guide Revision 7.2022. Dec 2022.
[2] Maria L 7. (2017, October 8). *Low cost spirometer*. Instructables.
[3] International Organization for Standardization. (2013). *Medical Devices—Requirements with guidance for use* (ISO Standard No. 11073-20101:2004-12-15).