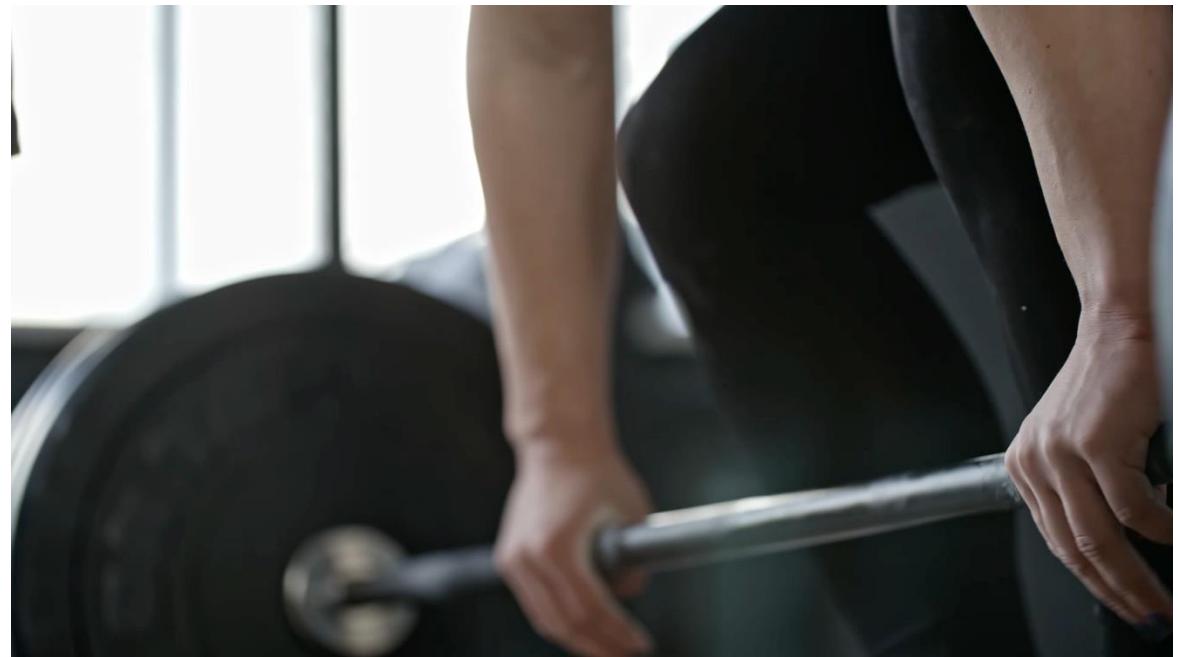
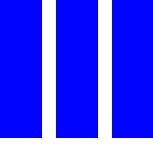


Nyal , Matthieu, Andrea

**Flex**

**Count on it!**

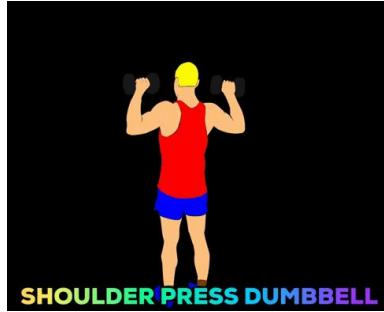




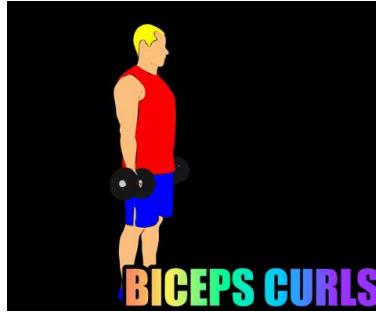
# **Overview and Application**



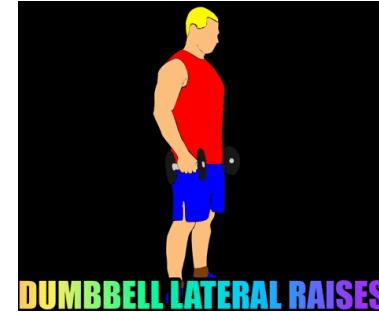
# To build and Exercise Monitoring System for:



&



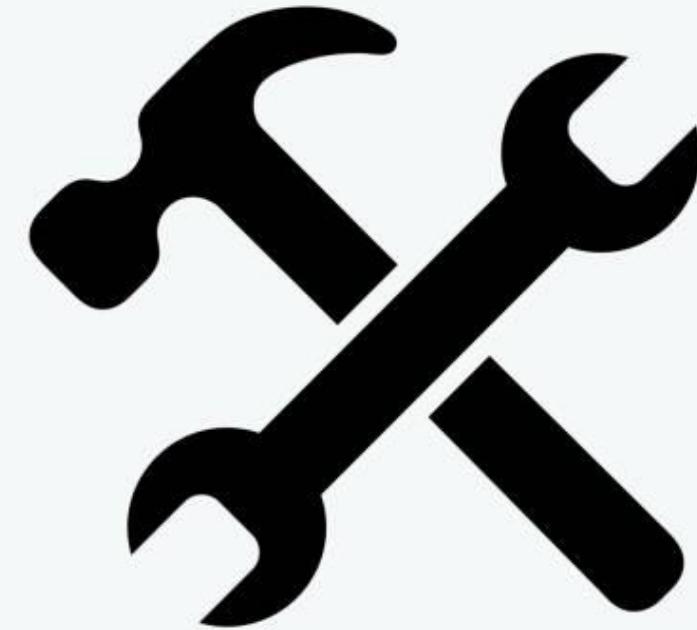
&



Using an **IMU** and **EMGs** to:

- Rep count ✓
- Classify weighted exercises in real-time ✓
- Classify fatigue level of muscles in real-time ✓

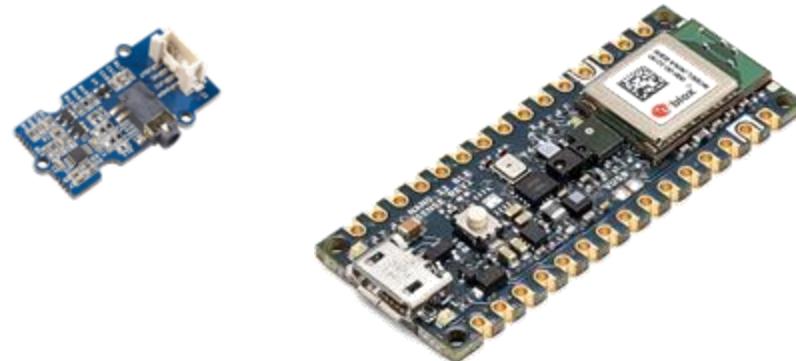
# Hardware



# Hardware (Electrical)

- **IMU-Device** 

- Arduino Nano BLE Sense Rev 2
- Dual AAA battery supply
- Velcro Strap x2

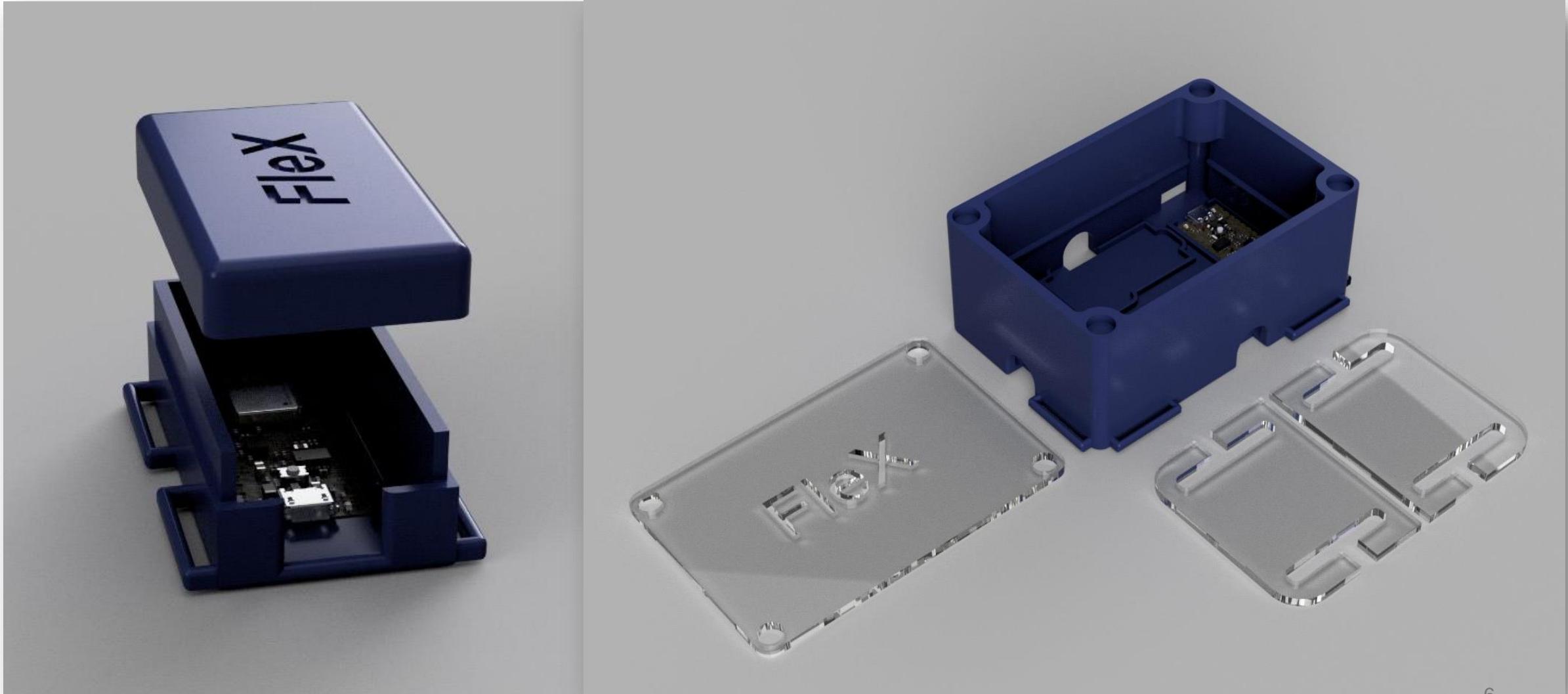


- **EMG-Device** 

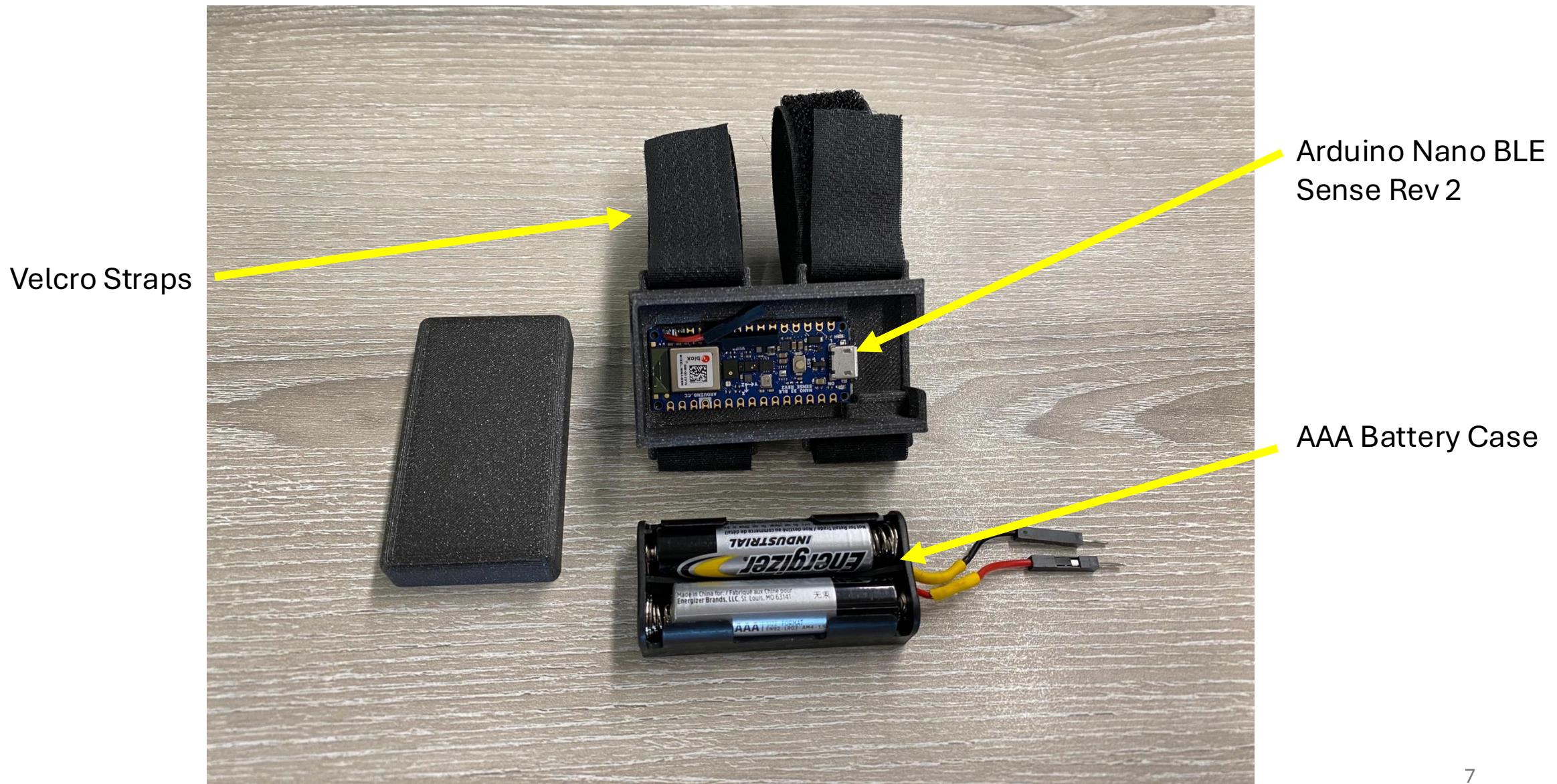
- Arduino Nano Ble Sense Rev 2
- Grove EMG Detector Sets x3
- Dual AAA battery supply
- 4x2mm Neodymium Magnets
- Velcro Strap x2



# Hardware



# Wrist-Worn IMU

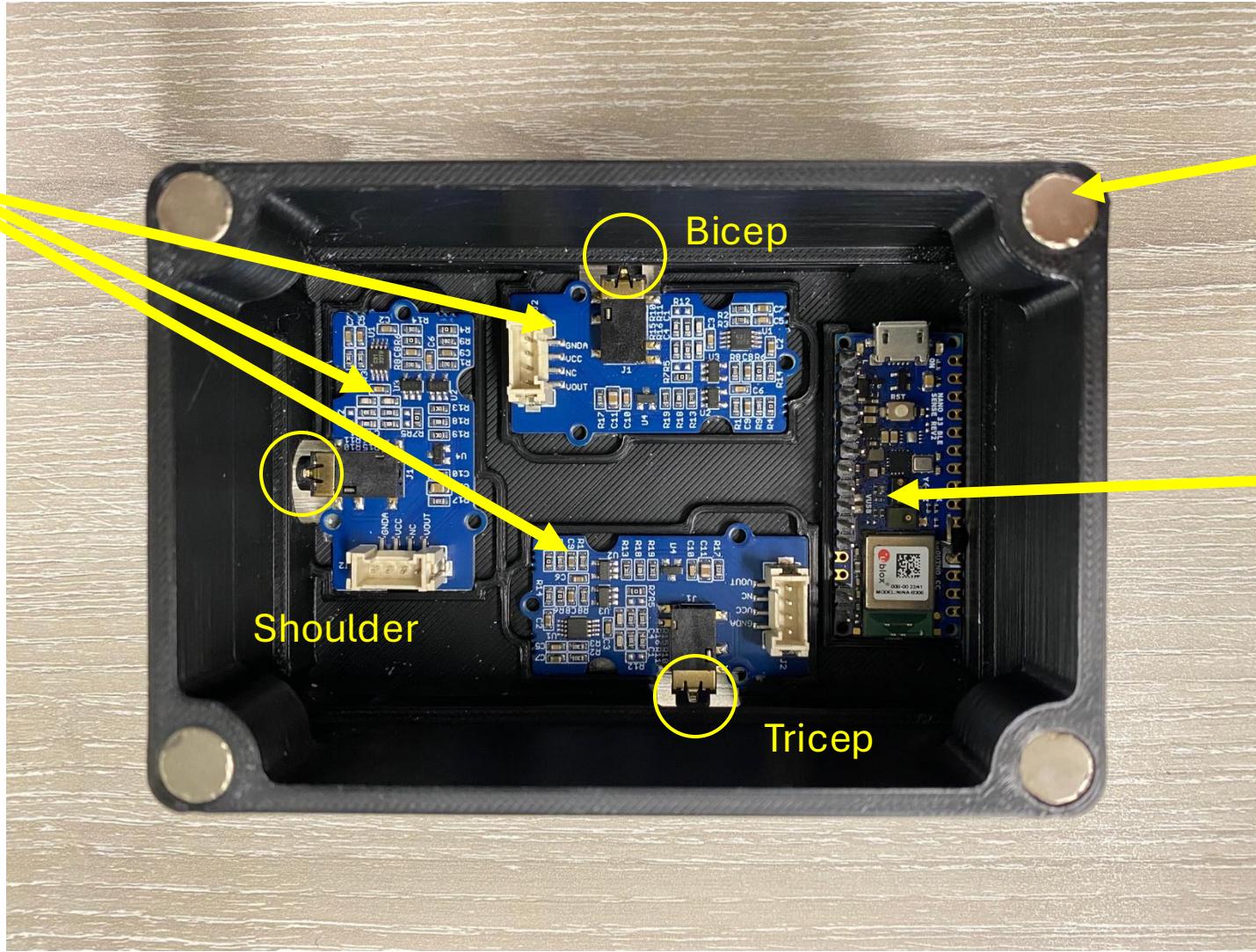


# Chest-Worn EMGs

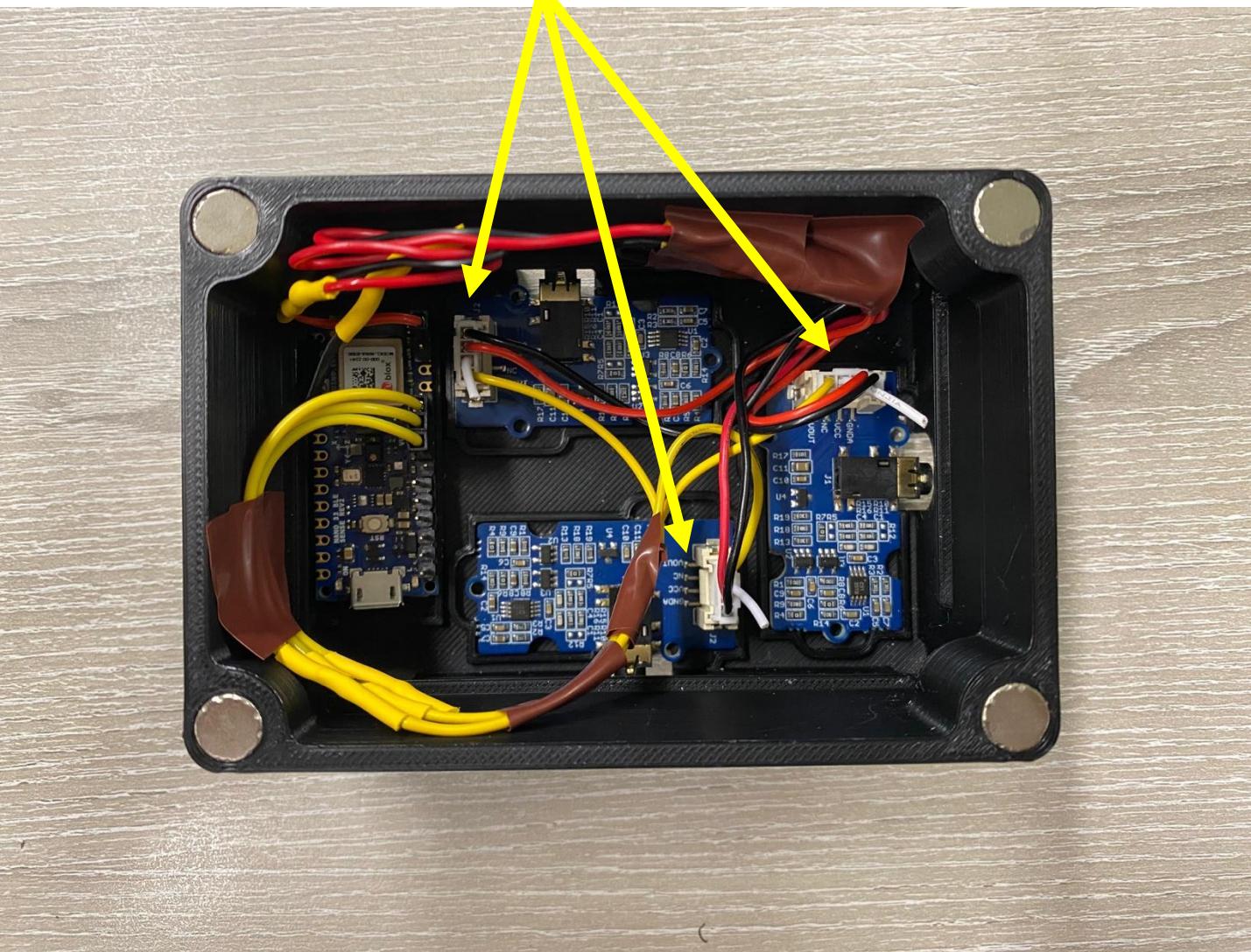
Grove  
EMG Detector

Neodymium  
magnets

Arduino Nano  
BLE



With All Removable Connectors



# Overall Hardware



### FleX

**Data Files Browser**

Browse and visualize your recorded session data files.

**Available Data Files**

- [All Files](#)
- [EMG Files](#)
- [IMU Files](#)
- 
- utf\_imu.csv**
- Type: IMU Data
- Created: 17/03/2025, 21:32:35
- Records: 6451
- Size: 674.8 KB
- [View Details](#)
- [Download](#)

**Data Visualization**

Time Range: All Data

Accelerometer	Gyroscope
<input checked="" type="checkbox"/> Accel_X	<input checked="" type="checkbox"/> Gyro_X
<input checked="" type="checkbox"/> Accel_Y	<input checked="" type="checkbox"/> Gyro_Y
<input checked="" type="checkbox"/> Accel_Z	<input checked="" type="checkbox"/> Gyro_Z

IMU Data Visualization

Value

Time

### FleX

**IMU Data Collection**

**Device Connection**

Status: Disconnected

IMU: Disconnected

[Connect to IMU](#) [Disconnect](#)

**Data Recording**

Recording File Name:

The file will be saved as [filename].imu.csv

[Start Recording](#) [Stop Recording](#) 0 reps

**Live Data**

Accelerometer	Gyroscope
X: <b>0.00</b>	
Y: <b>0.00</b>	
Z: <b>0.00</b>	

Accelerometer Live Data

Value

Samples

Accelerometer	Gyroscope
X: <b>0.00</b>	
Y: <b>0.00</b>	
Z: <b>0.00</b>	

Gyroscope

### FleX

**EMG Data Collection**

**Device Connection**

Serial Port: COM3 or /dev/cu.usbmodem213301

Baud Rate: 115200

[Connect](#) [Disconnect](#)

Status: Disconnected

EMG: Disconnected

**Data Recording**

Recording File Name:

The file will be saved as [filename].emg.csv

[Start Recording](#) [Stop Recording](#) 0 reps

**Live Data**

EMG Readings
Time: <b>0</b>
Bicep: <b>0</b>
Shoulder: <b>0</b>
Tricep: <b>0</b>

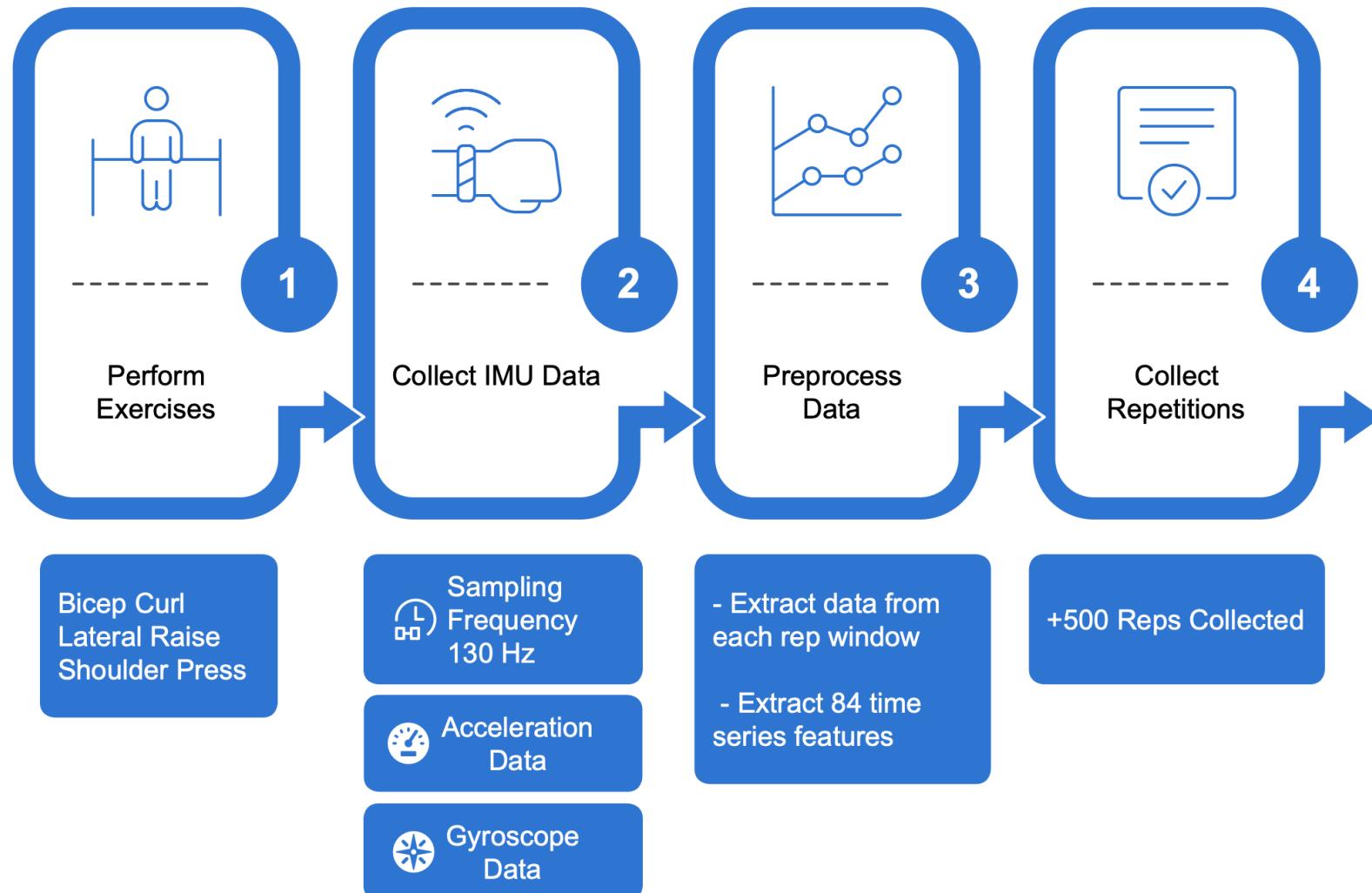
EMG Live Data

Amplitude

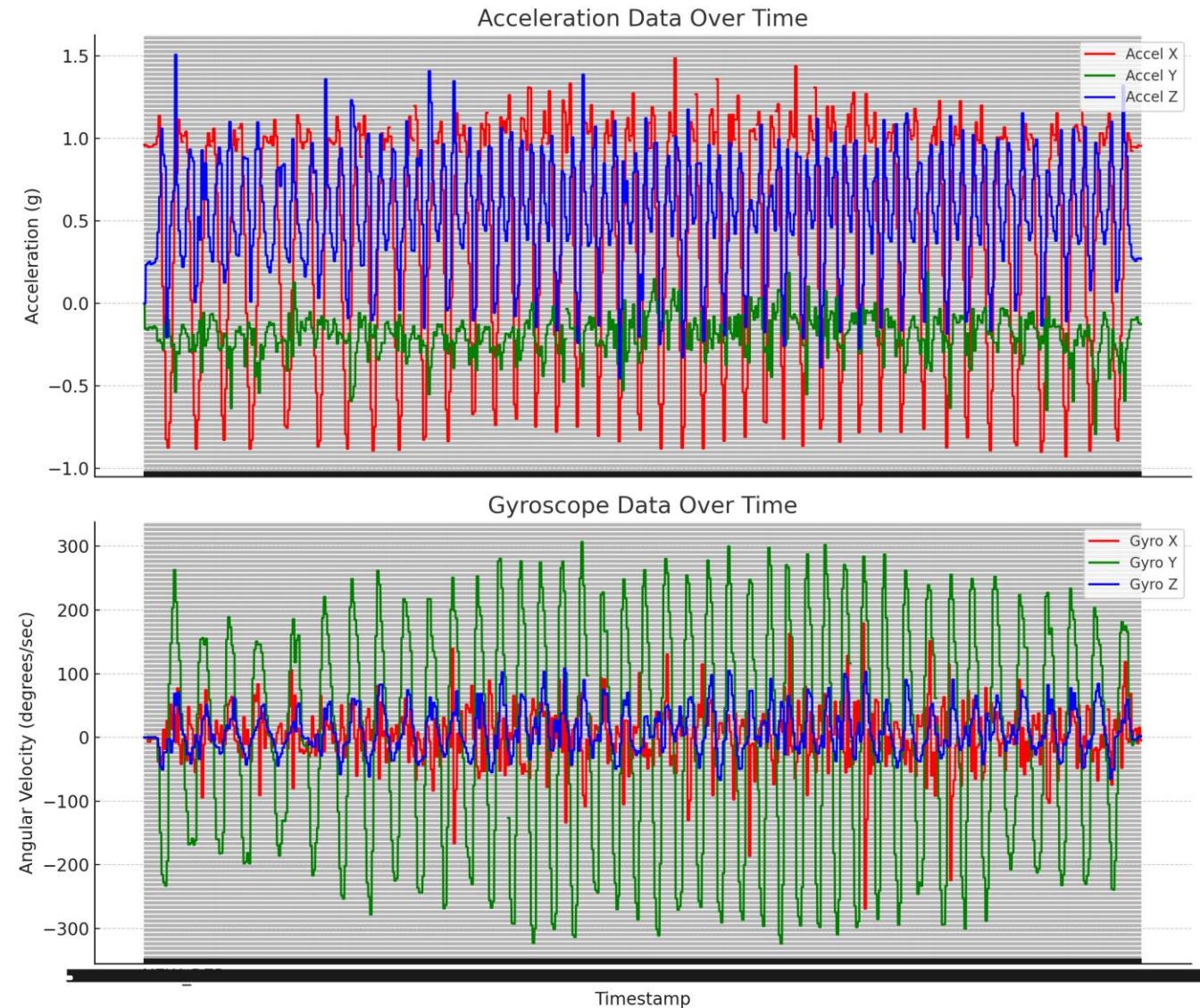
Samples

# Data Collection

# IMU Data Collection



# IMU Data Collection: Raw Data



# EMG Data Collection

**Muscles Monitored:** Shoulder & Biceps

**Sampling Rate:** 1000Hz EMG signal collection

**Preprocessing:** Extract data from each rep window, then extract 144 time series features

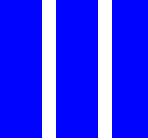
**Repetitions:** 300 weighted reps per exercise (240 train Matt Nyal, 80/exercise, 60 test Andrea, 20/exercise)

## Fatigue Labelling:

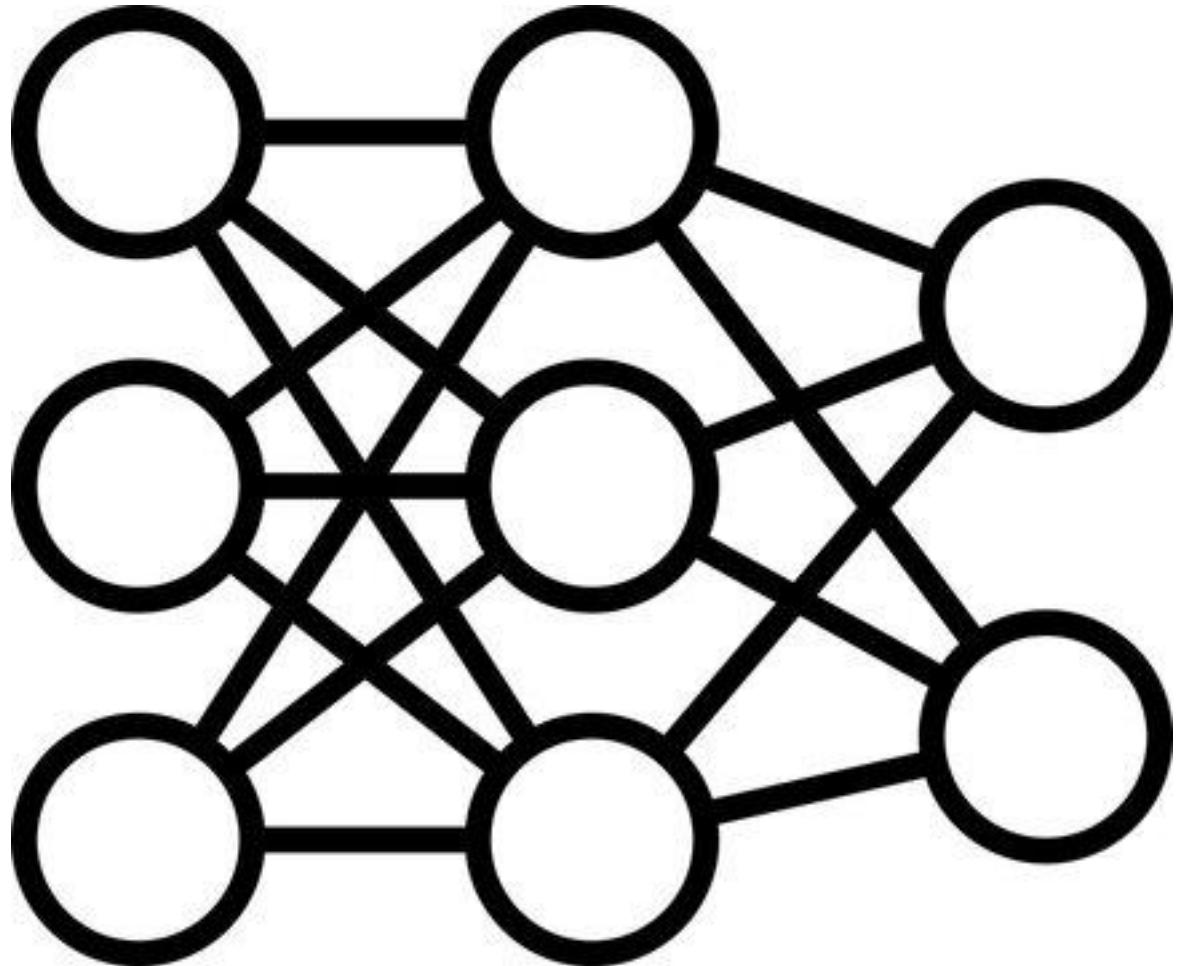
- Repetitions completed **until failure**
- Large rest periods included
- Fatigue levels assigned when going to failure:  **Low (1/3 of reps)** |  **Medium (1/3 of reps)** |  **High (1/3 of reps)**
- Also collected data where the user lifted varying weights and classified fatigue accordingly and also varied speed of reps. (low for all reps when weight was light)
- 80% failure data (12kg), 20% low weight data (2kg)

# EMG Data Example



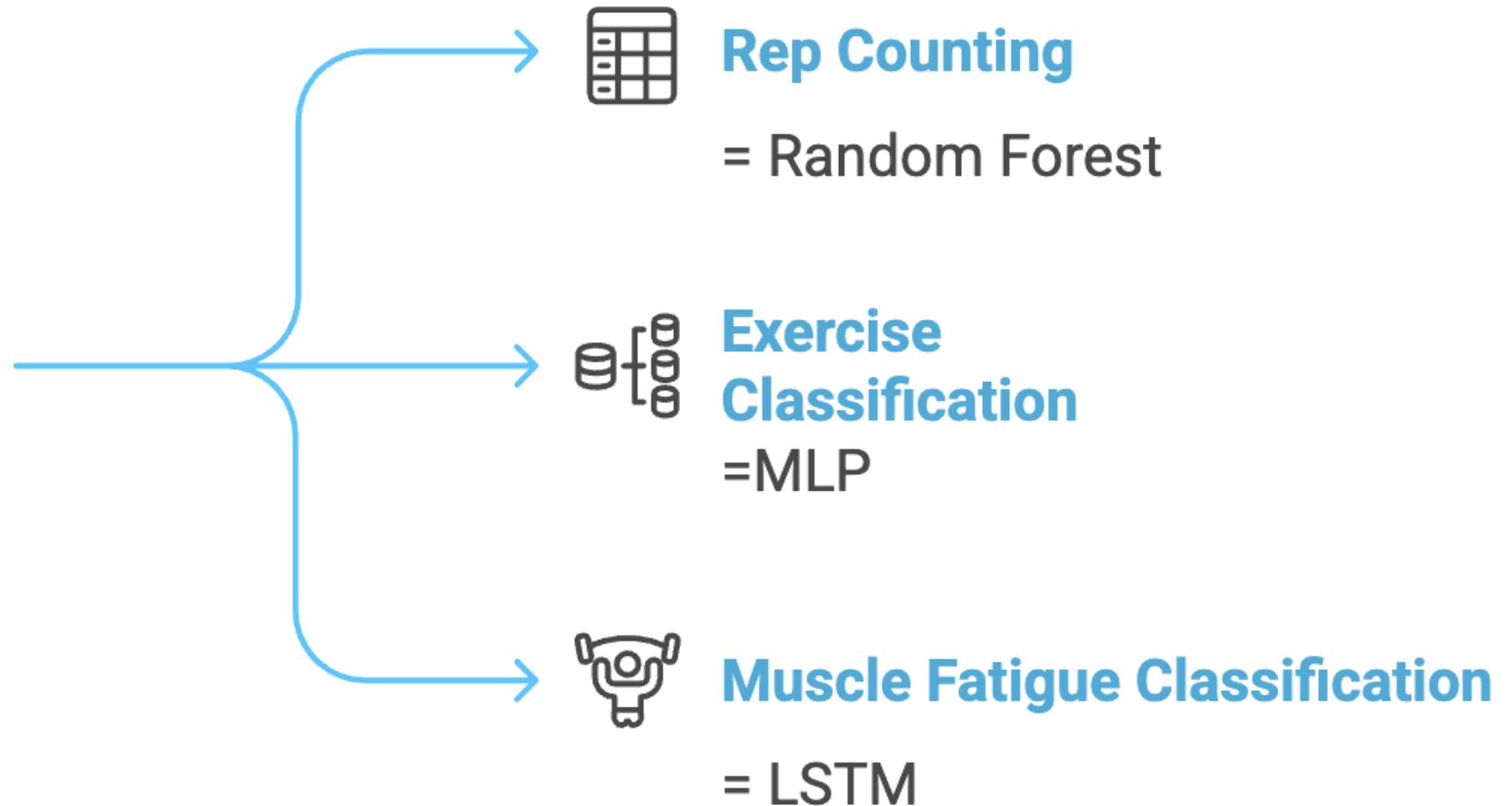


# ML Algorithms

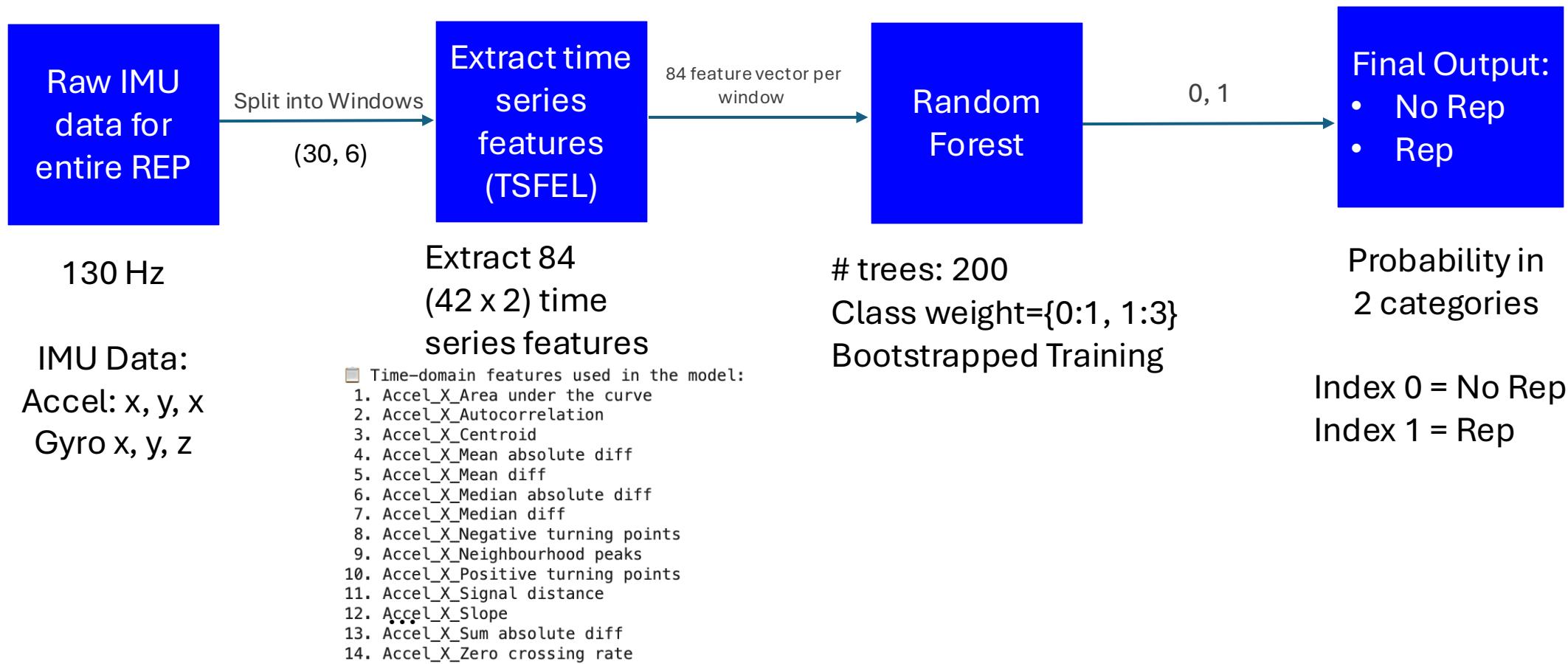




**Which algorithm  
should be used for  
the specific fitness-  
related task?**



# Rep Counting Architecture

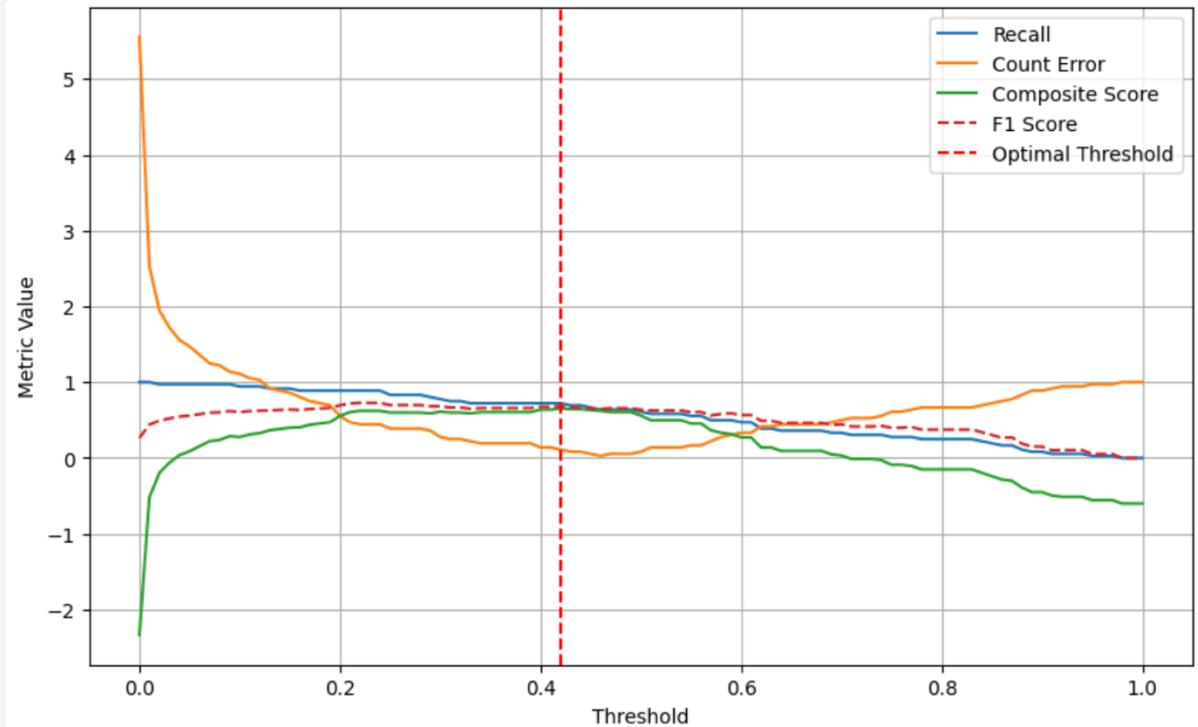


# Rep Counting (results)

Recall : 0.72

Count Error : 0.11

Grid Search Result for Optimal Threshold ( $t = 0.42$ )



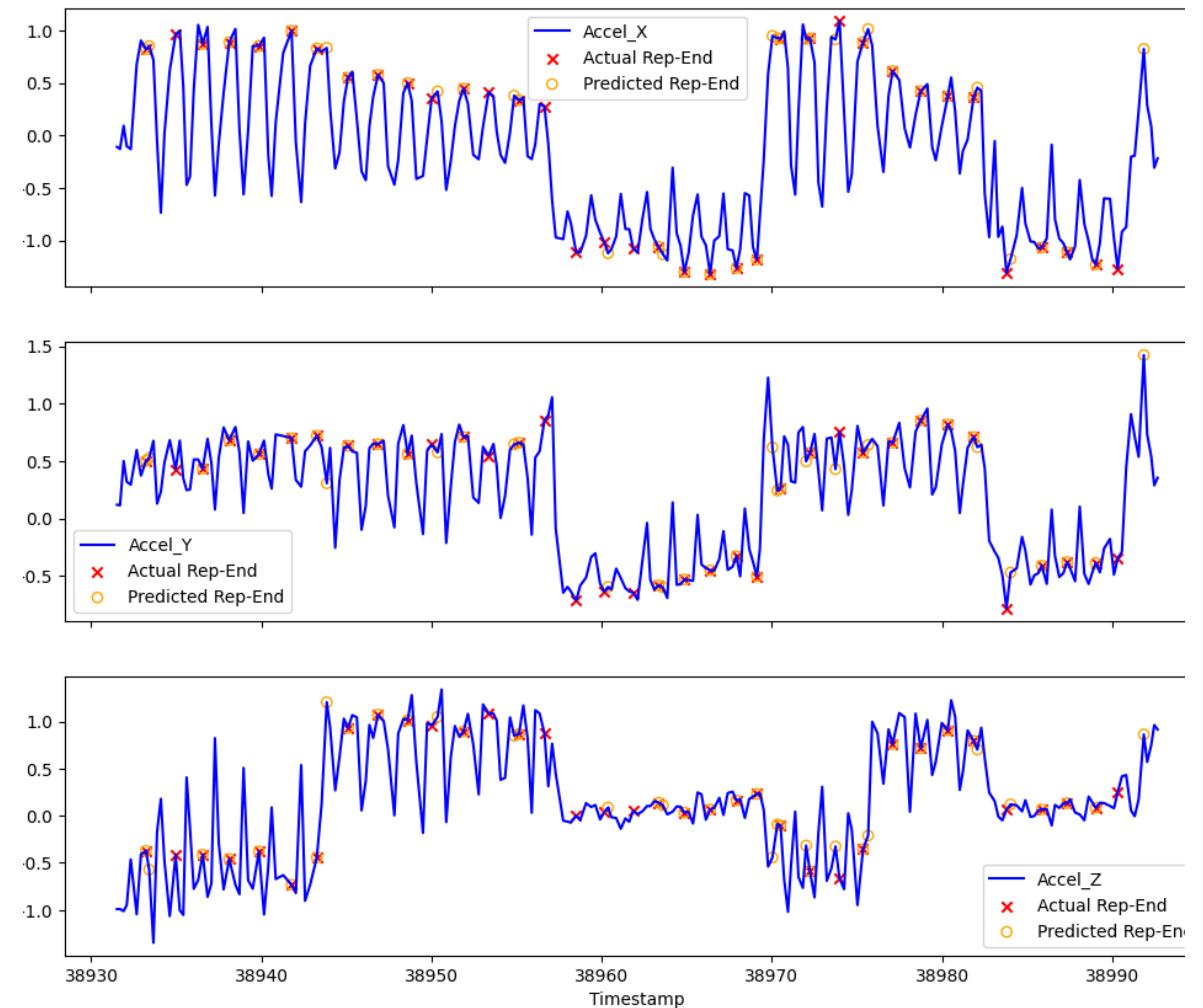
Composite Score:  $\max_{\text{threshold}} \left( \text{Recall} - \alpha \times \frac{|\text{predicted count} - \text{true count}|}{\text{true count}} \right)$

# Rep Counting (results)

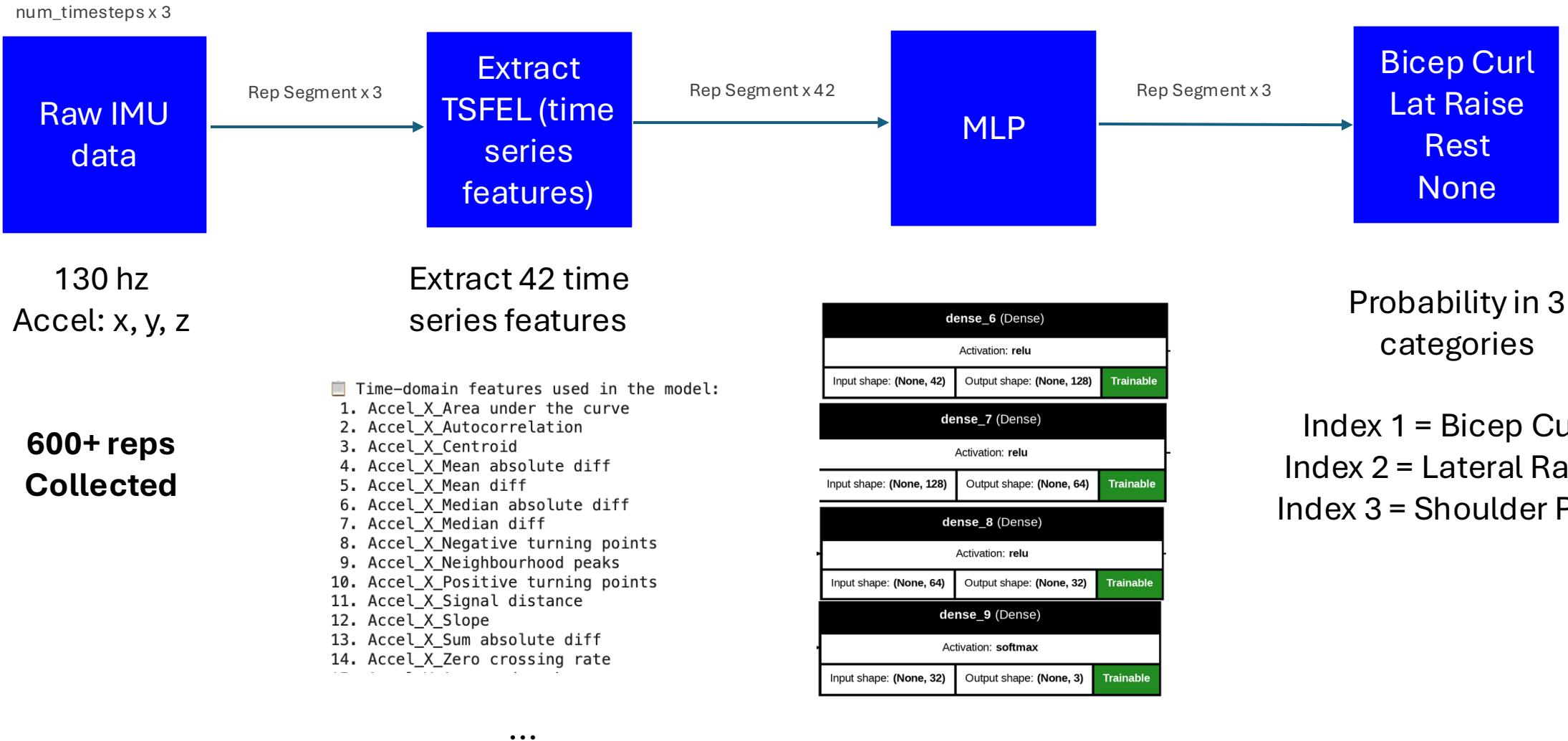
LSTM: Test Loss: 0.237, Test Accuracy: 0.877

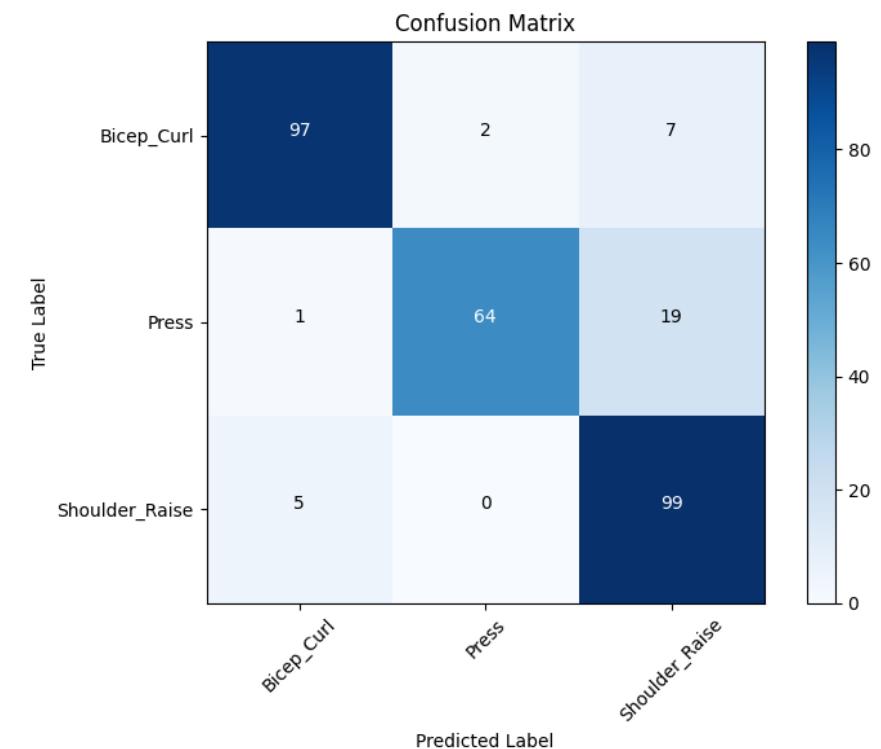
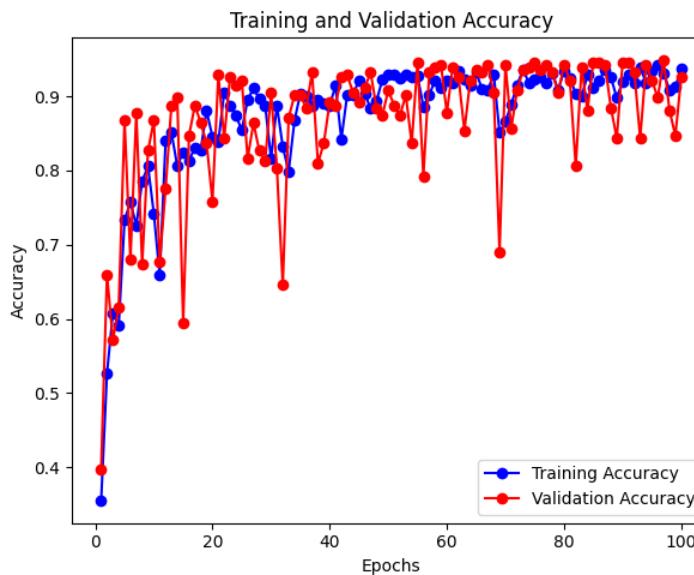
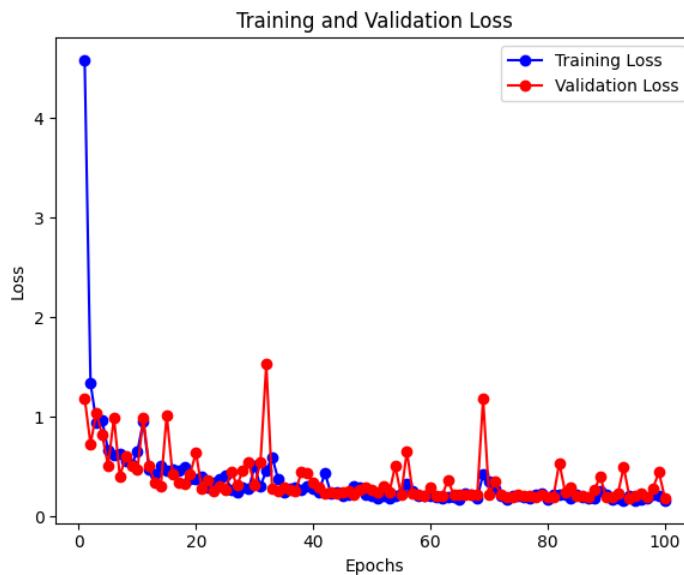
	precision	recall	f1-score
0	0.92	0.94	0.93
1	0.63	0.53	0.58

Test Data: Actual vs. Predicted Rep-End Windows



# Exercise Classification Architecture





Classification Report:

	precision	recall	f1-score	support
Bicep_Curl	0.88	0.94	0.91	106
Press	0.95	0.98	0.96	84
Shoulder_Raise	0.96	0.87	0.91	104
accuracy			0.93	294
macro avg	0.93	0.93	0.93	294
weighted avg	0.93	0.93	0.92	294

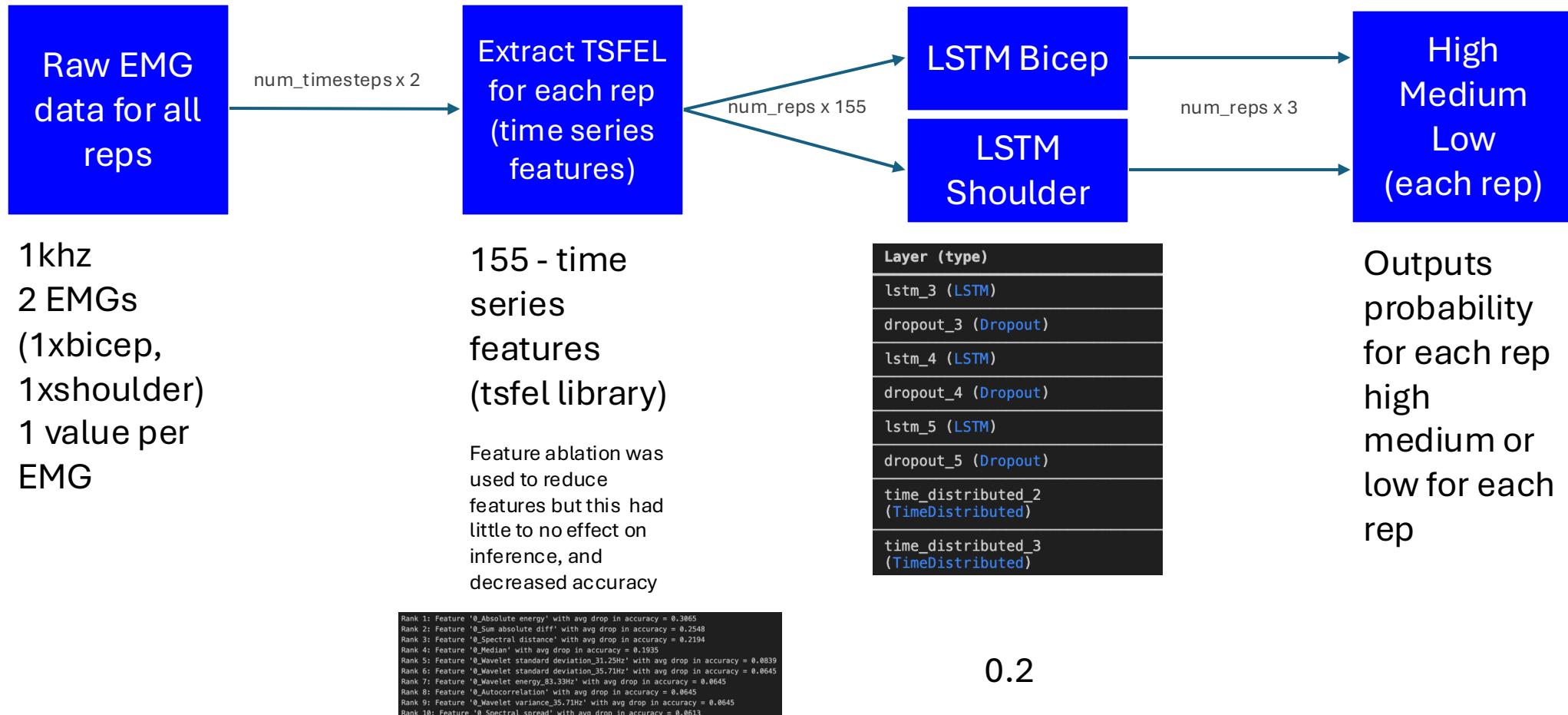
Weighted F1 Score: 0.9250  
Weighted Recall: 0.9252

Training Accuracy: 93.2% (Matt, Nyal)  
Validation Accuracy: 92.5% (Andrea)

Other Models:

CNN Validation Acc: 55.6%  
LSTM Validation Acc: 90.2%

# Muscle Fatigue Architecture



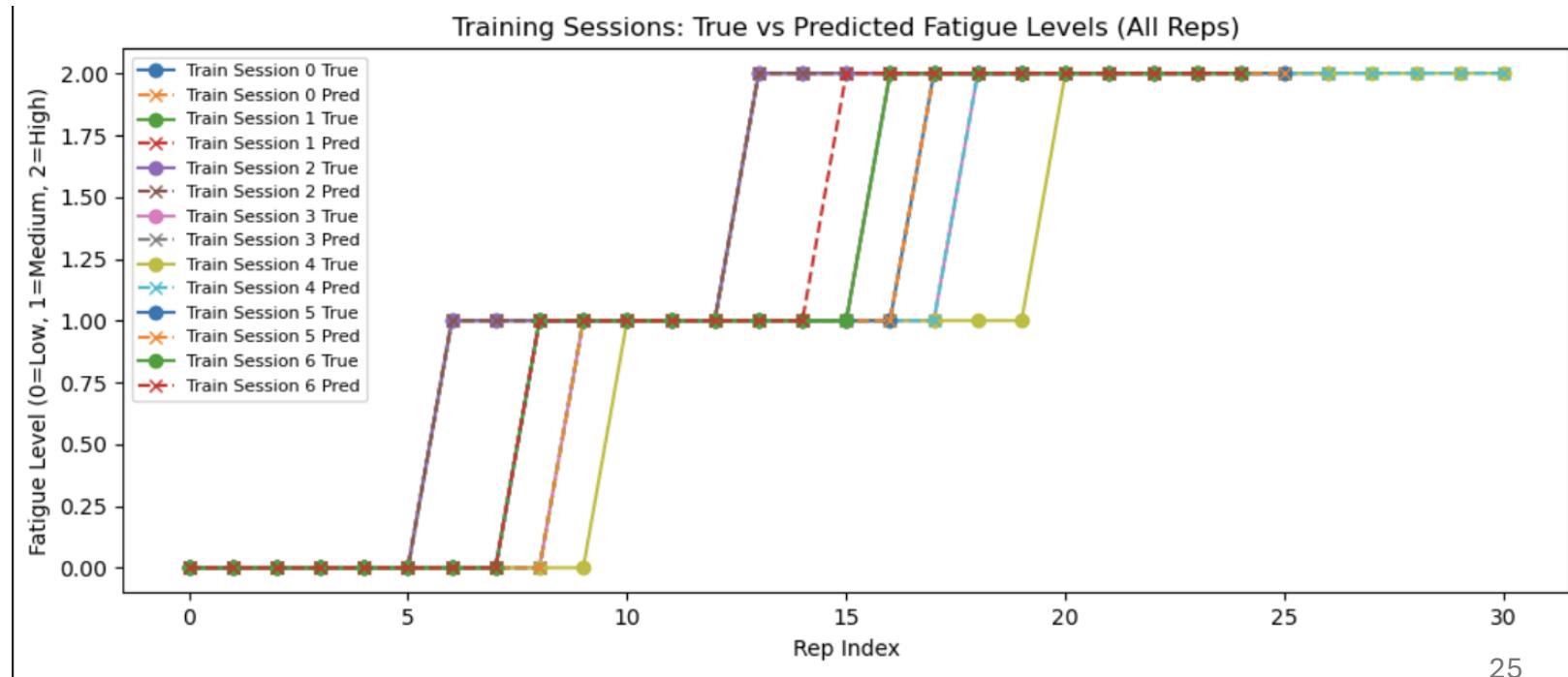
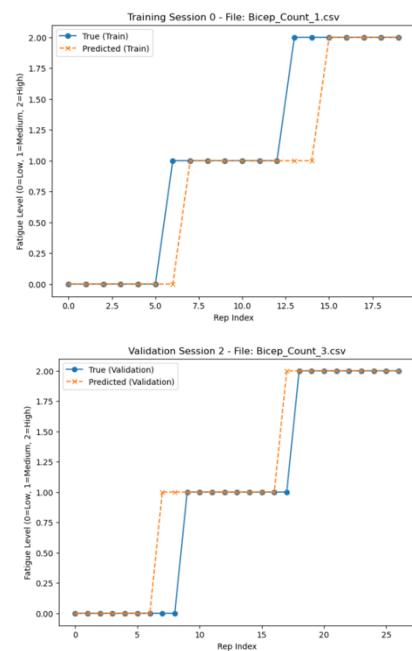
MLP, SVM (wasn't able to work in real time, low accuracy, overfitted)

RNN (as the session length is long RNN had low accuracy as wasn't able to model long term dynamics<sup>23</sup>)

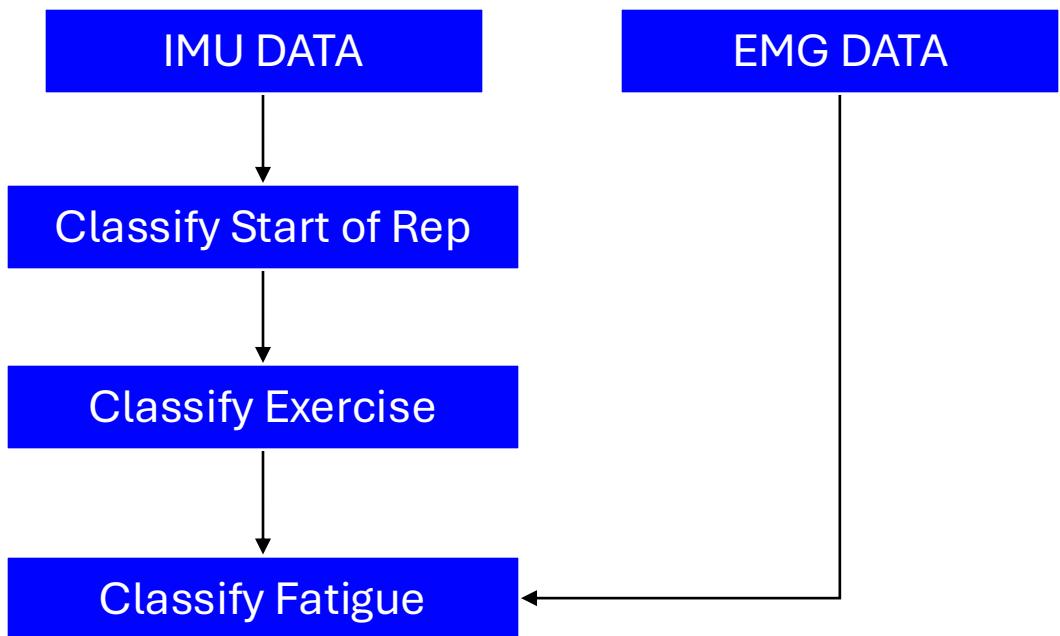
# Muscle Fatigue (results)

Training Accuracy: 73.71% (Nyal, Matt)

Validation Accuracy: 71.87% (Andrea)



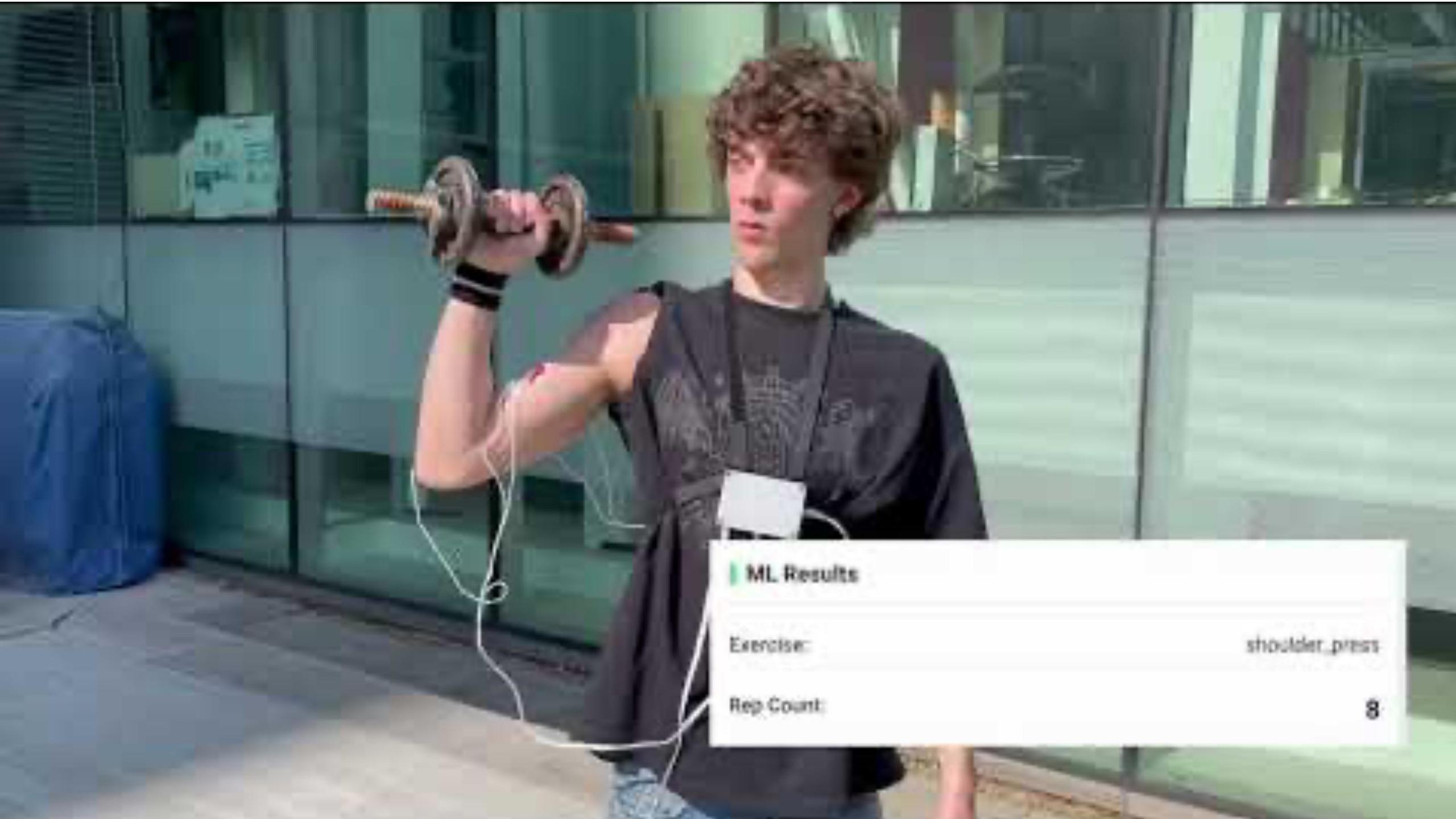
# Overall Flow



# Final Results (Demo Video)

The screenshot shows the FleX dashboard with the following sections:

- Setup Connection:** Fields for Session Name (empty), EMG Serial Port (/dev/cu.usbmodem213301), and EMG Baud Rate (115200). Buttons for Start Session and Stop Session.
- Status:** Status: Ready, IMU: Disconnected, EMG: Disconnected.
- Rep Detection Mode:** A toggle switch set to Automatic.
- Data Monitoring:** Sections for IMU Data and EMG Data.



ML Results

Exercise:

shoulder\_press

Rep Count:

8

