

WIRELESS EMG MUSCLE FATIGUE MONITORING SYSTEM

Sofia Iturbide'26, Kaleigh Spencer'26, and Professor Joseph Palladino
Trinity College, Hartford, CT

PROBLEM DEFINITION AND BACKGROUND:

Muscle fatigue: A decline in a muscle's ability to generate force, often caused by repeated exercises that target the same muscles. [1] Mild muscle fatigue indicates a healthy workout and muscle strengthening while excessive muscle fatigue can lead to muscle injury. The goal of the **MuscleTrack system** is to help athletes identify what muscles they are fatiguing to optimize their workout.

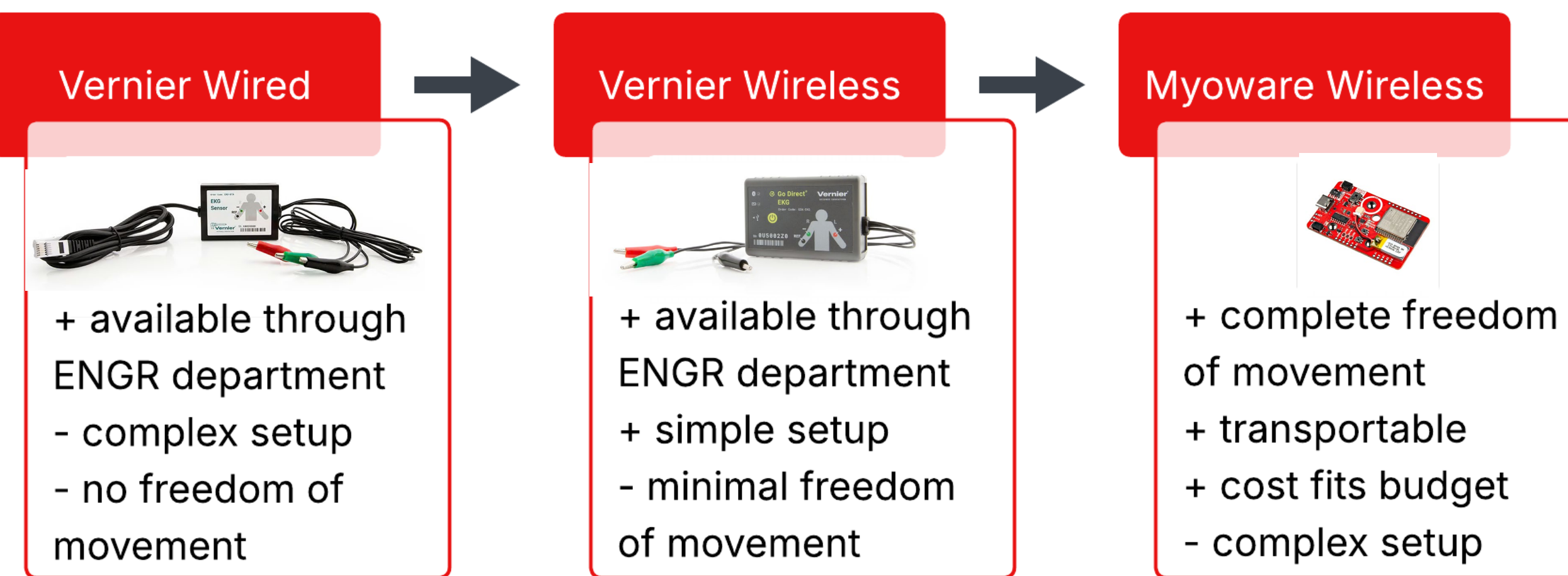
DESIGN ALTERNATIVES:

Wired vs. Wireless
Wireless sensors provide more freedom of movement and less signal noise.

Muscle Selection
Surface level, large muscles work best for accurate placement and EMG detection.

Sensor Purchase
SparkFun Myoware2 sensors were selected to meet the wireless condition within budget.

DESIGN EVALUATION AND ITERATIVE PROCESS:



- Sampling rate: 400Hz.
- Muscle contraction electrical frequencies typically fall between 1 and 100Hz. [3]
- Centroid calculated between 10 and 120Hz.

Fatigue Detection:

- Literature identifies decreased centroid frequency as a sign of muscle fatigue. [2]
- **Centroid frequency (CF)** is the weighted average of the signal frequencies, using the magnitude of each frequency as the weight.
- Nerve conduction velocity decreases with fatigue, causing a decrease in detected frequencies. [4]

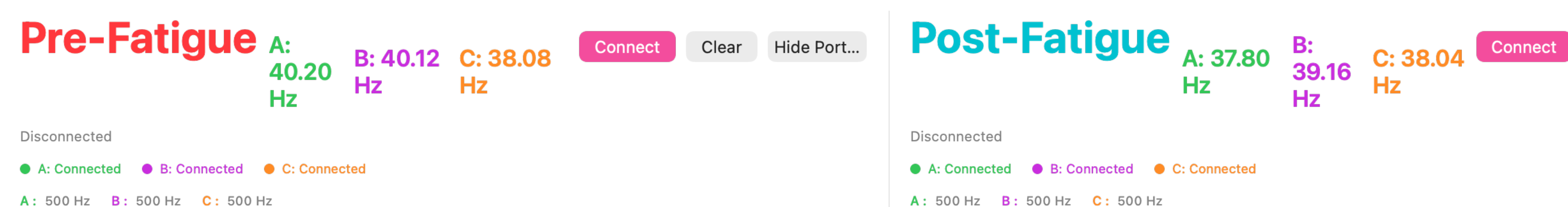
$$CF = \frac{\sum_k (f_k S_k)}{\sum_k S_k}$$

$f_k = \text{frequency}$
 $S_k = \text{amplitude}$

$$\%CF = \frac{CF}{\text{sampling rate}}$$

USER INTERFACE: 1) Put EMG sensor on the muscles desired to test.

2) Click connect to start data taking pre workout and again to collect post.



3) Click analyze to calculate change in centroid frequency and detect fatigue.

Sensor Summary				
Muscle	Pre	Post	Diff	Status
bicep	20.1%	18.9%	-1.2%	no fatigue
tricep	20.1%	19.6%	-0.5%	no fatigue
deltoid	19.0%	19.0%	-0.0%	no fatigue

REFERENCES:

- Al-Mulla, M. R., Sepulveda, F., & Colley, M. (2011). A review of non-invasive techniques to detect and predict localized muscle fatigue. *Sensors*, 11(4), 3545–3594.
- Cifrek, M., Medved, V., Tonkovic, S., & Ostojic, S. (2009). Surface EMG based muscle fatigue evaluation in biomechanics. *Clinical Biomechanics*, 24(4), 327–340.
- Doucet, B. M., Lam, A., & Griffin, L. (2012). Neuromuscular electrical stimulation for skeletal muscle function. *The Yale journal of biology and medicine*, 85(2), 201–215.
- Segizbaeva, M. O., Donina, Zh. A., Timofeev, N. N., Korolyov, Yu. N., Golubev, V. N., & Aleksandrova, N. P. (2013). EMG Analysis of Human Inspiratory Muscle Resistance to Fatigue During Exercise. In M. Pokorski (Ed.), *Neurobiology of Respiration* (pp. 197–205). Springer Netherlands.

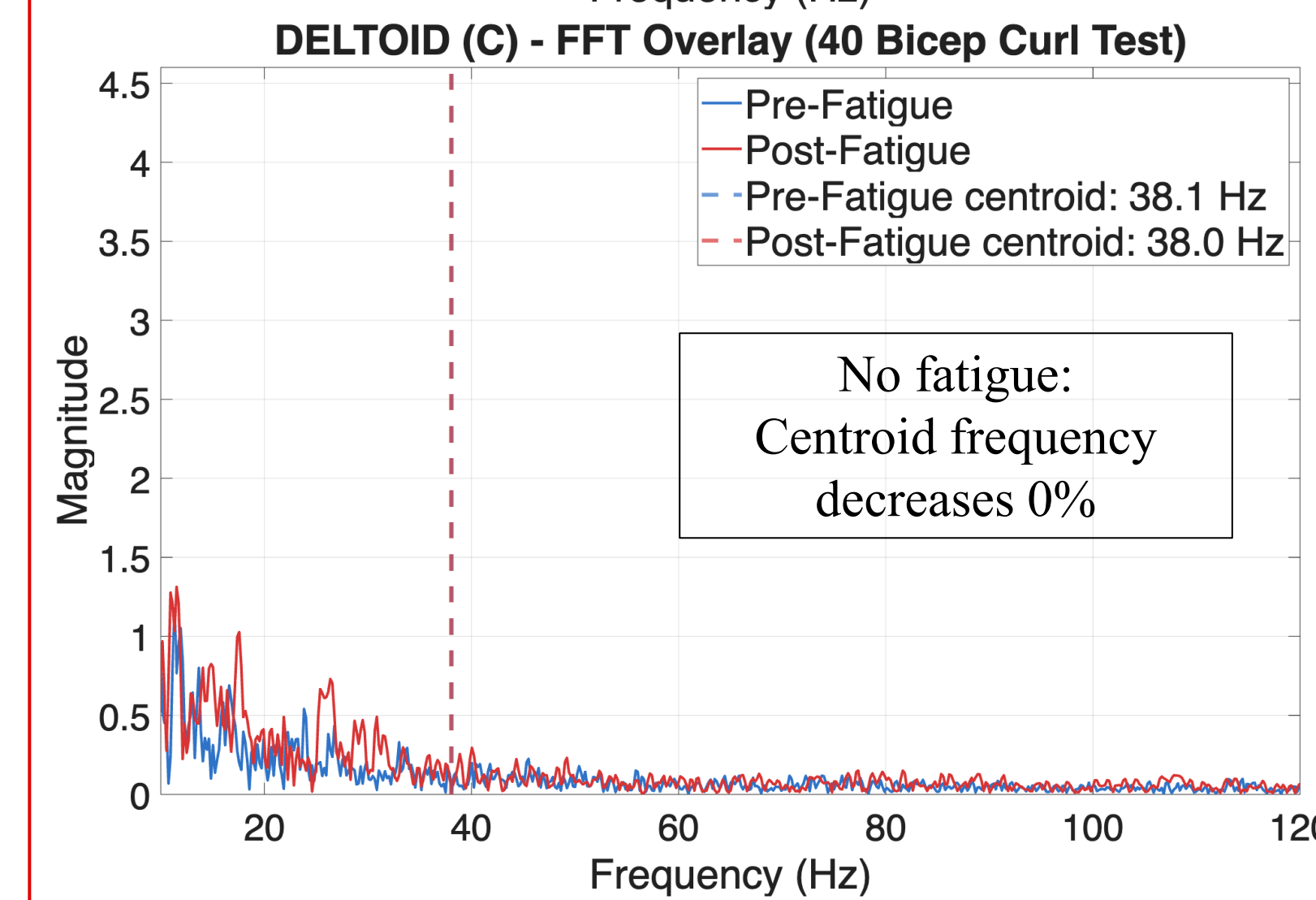
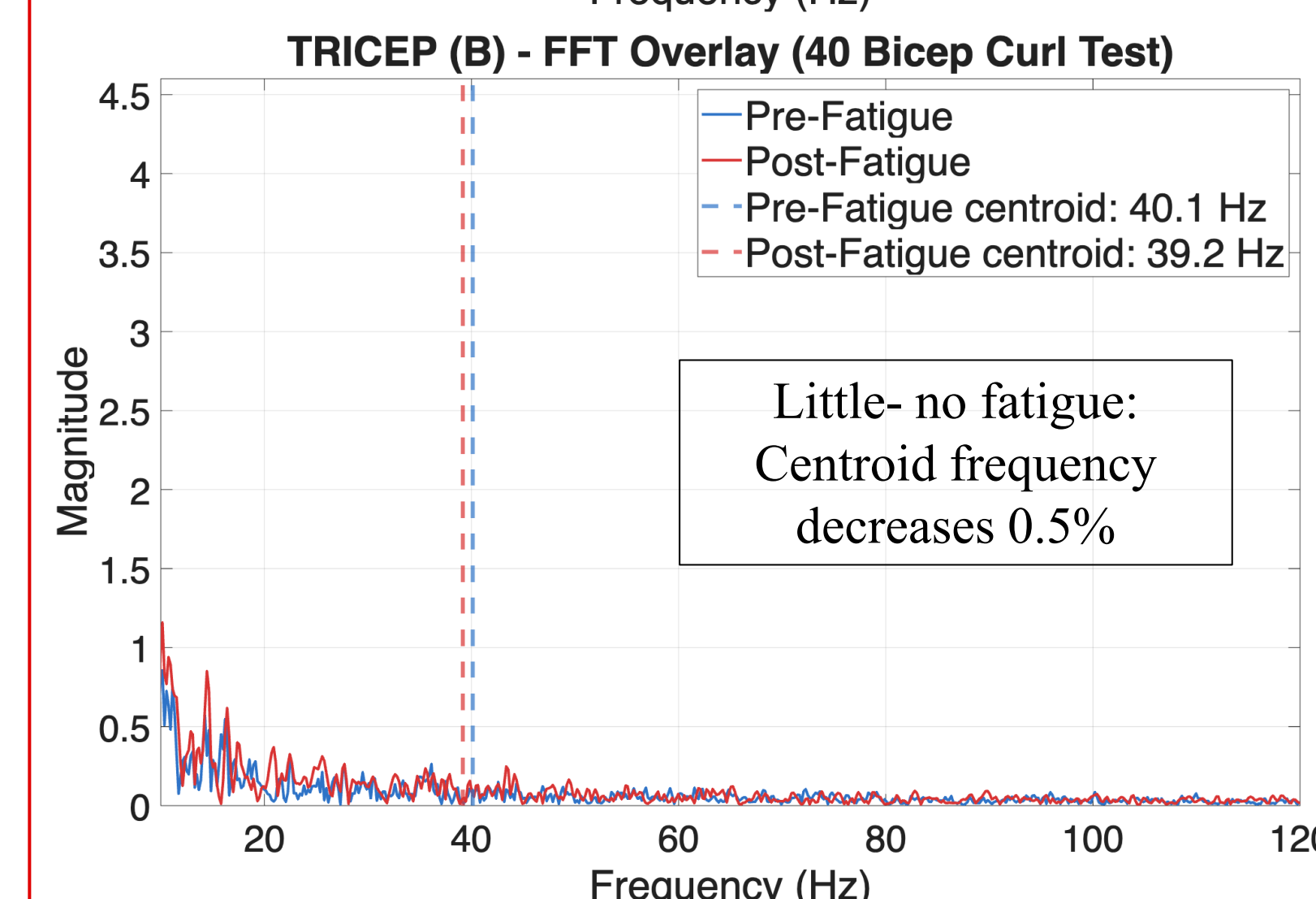
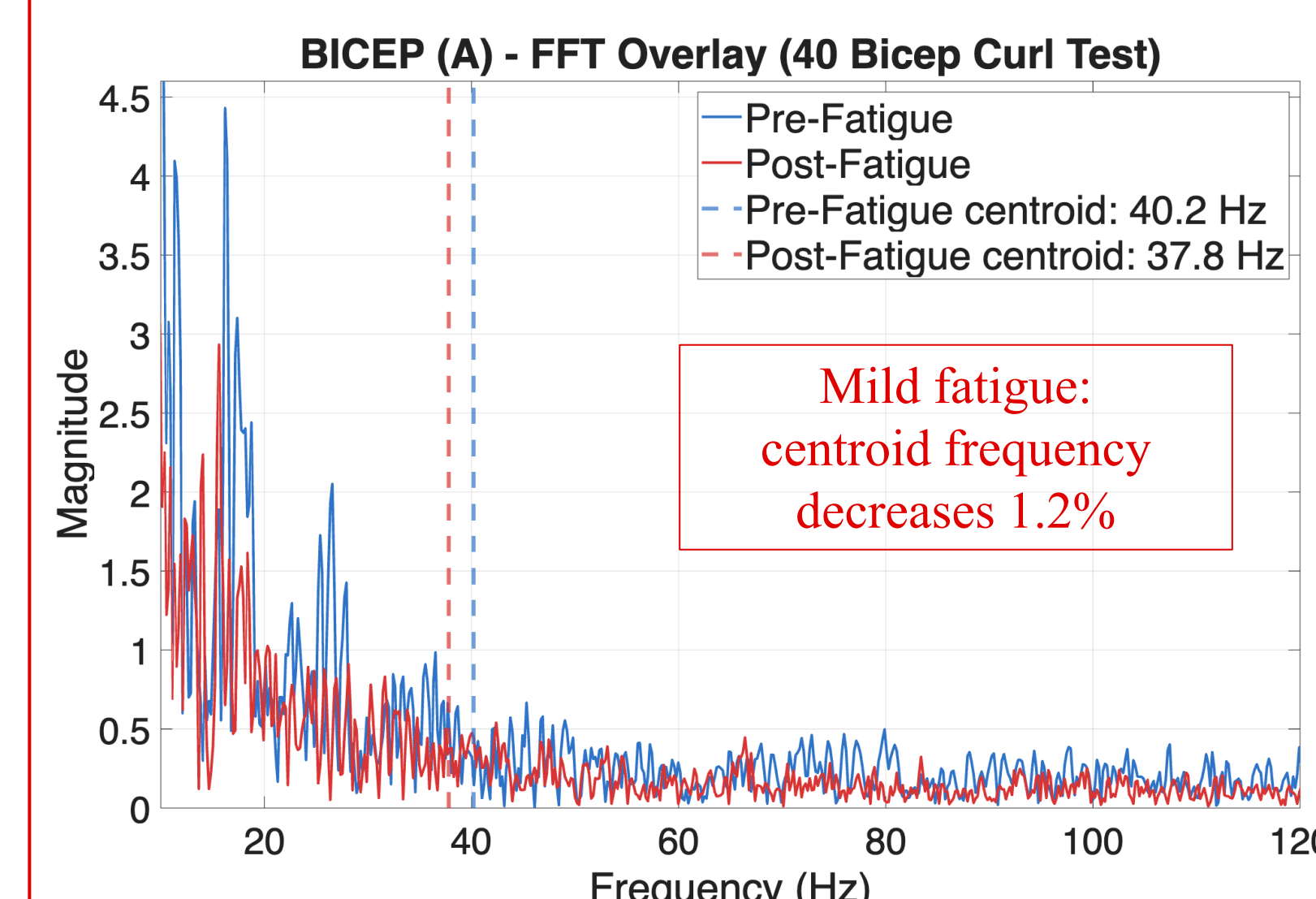
Supported, in part, by a grant from the NASA CT Space Grant Consortium

DESIGN REQUIREMENTS: The system must:

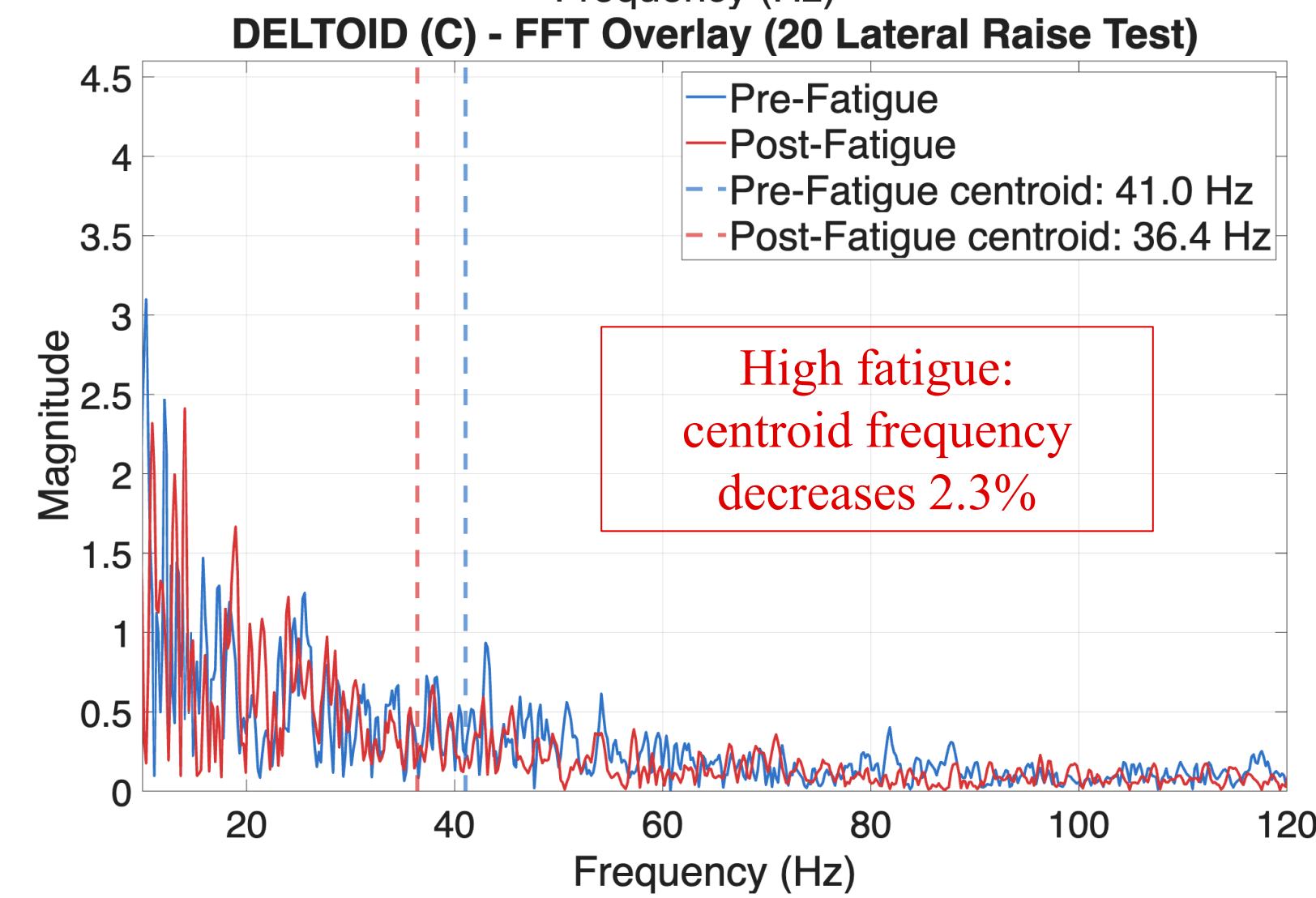
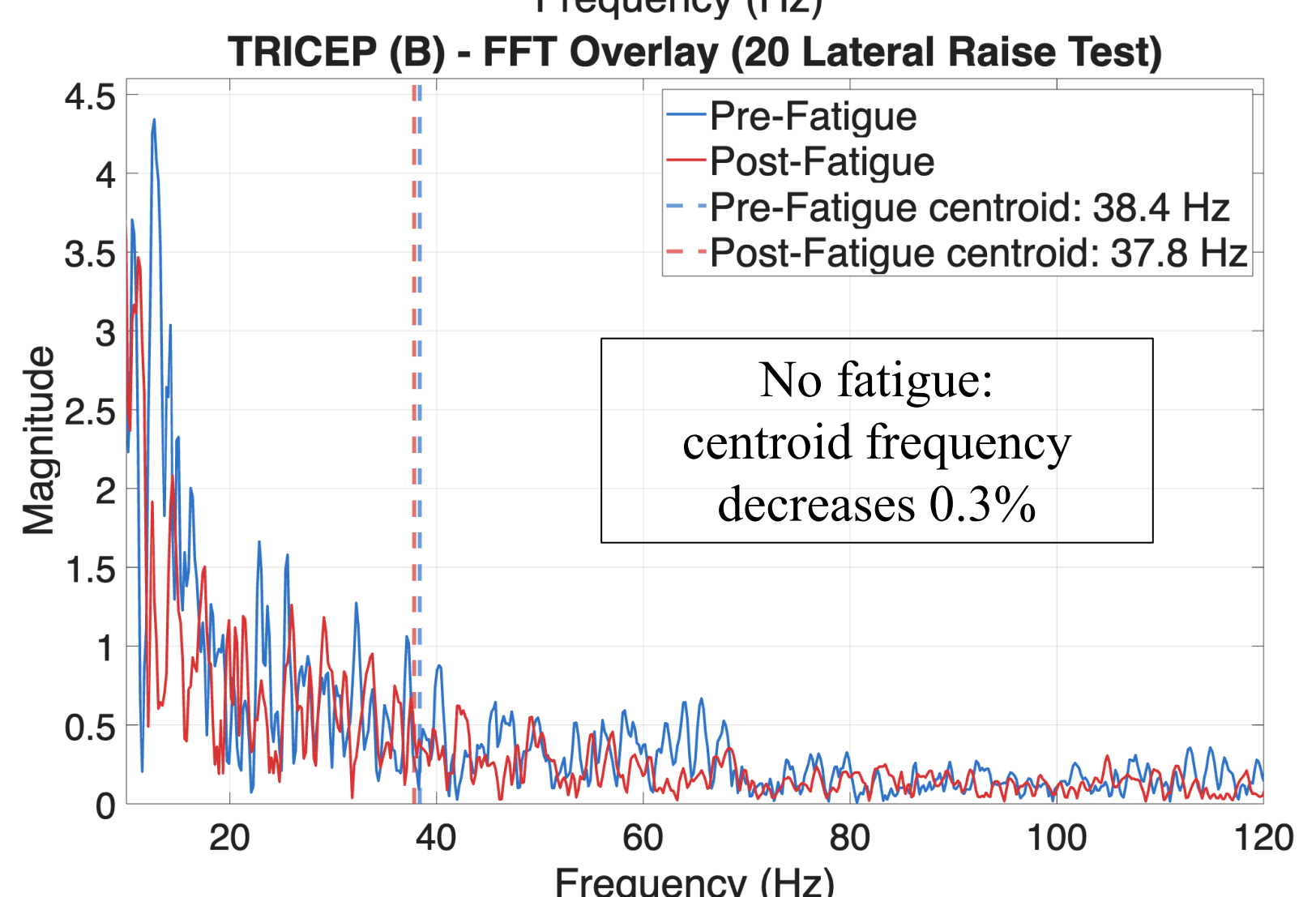
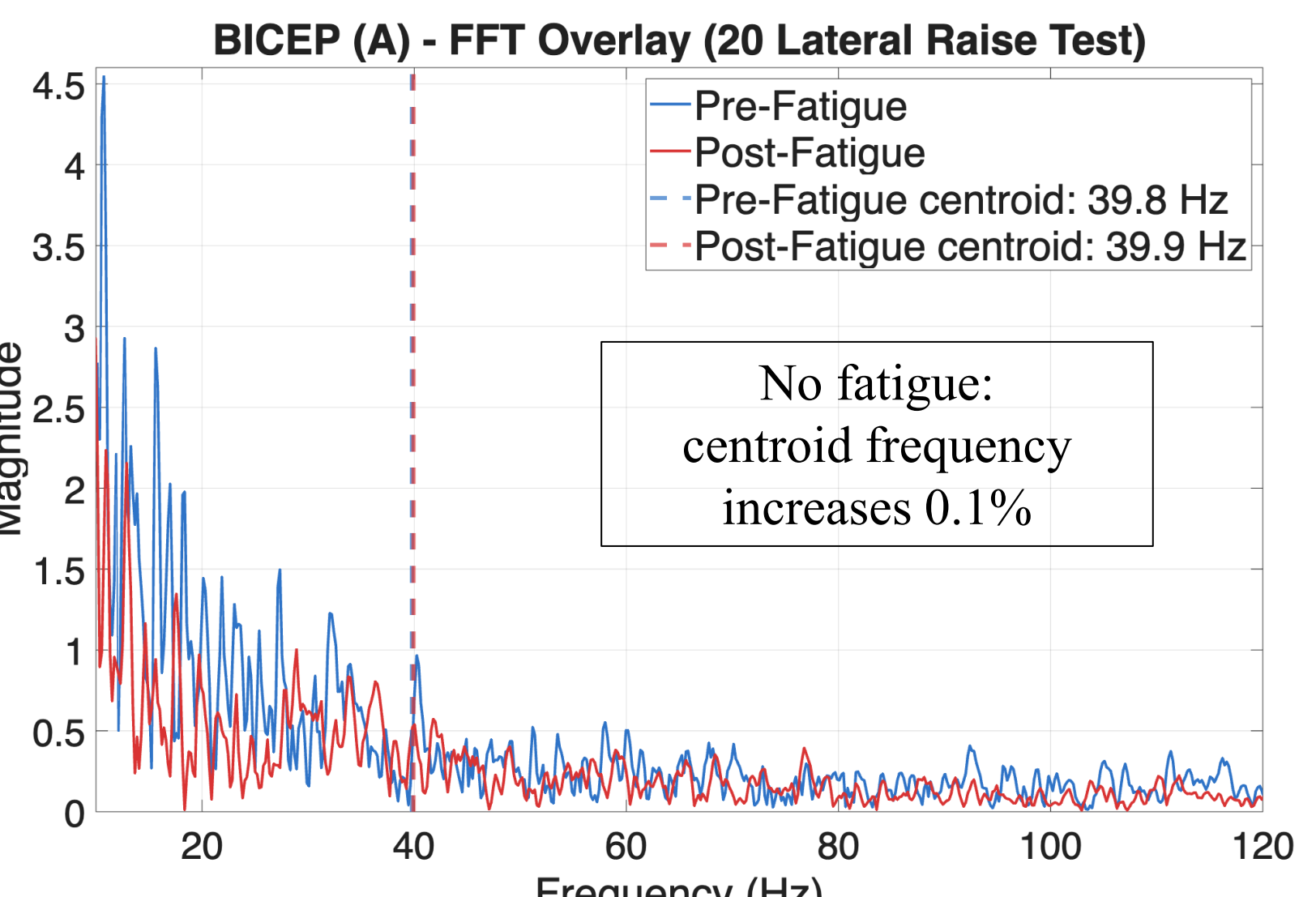
- Quantitatively detect muscle fatigue using the surface EMG signal.
- Be transportable and durable.
- Be easy to use with minimal training.
- Display results in a user-friendly manner on an app.
- Compare muscle fatigue levels across multiple muscles.
- Cost under \$1250.
- Comply with EMG placement and use protocols.
- Adhere to biomedical instrumentation safety standards.

FINAL DESIGN AND IMPLEMENTATION:

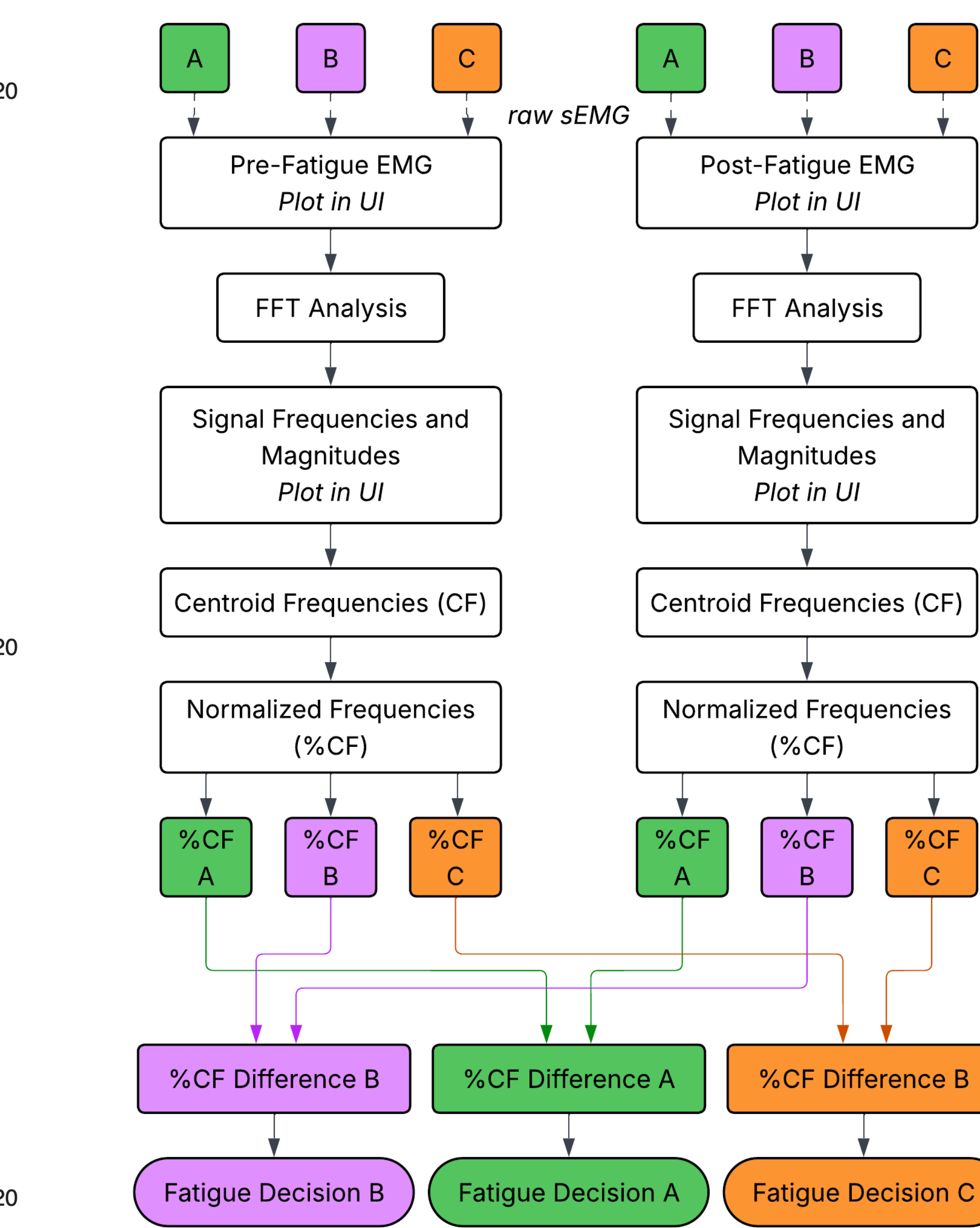
Bicep Curl Test: target biceps



Lateral Raise Test: targets deltoid



- Pre- and post-fatigue EMG data were collected during arm exercises using a 10lb dumbbell.
- Participants recorded 3 reps in 10 seconds, performed X reps to induce fatigue, then recorded 3 more reps.
- Participants were not previously fatigued that day.
- **Left-column graphs:** Fatigue seen in bicep, but not tricep or deltoid after bicep curls.
- **Right-column graphs:** Fatigue seen in deltoid, but no bicep or tricep after lateral raises.



DISCUSSION, CONCLUSION, AND RECOMMENDATIONS:

- The muscle track system can detect muscle fatigue in the bicep, tricep, deltoid, and latissimus for any arm exercise performed in repetition.
- Decreases in centroid frequency between -0.5% and -2.0% are considered mild fatigue. Decreases over -2.0% are considered high fatigue.
- Users can test their form for various exercises to make sure they are fatiguing the correct muscle.
- The system also has potential to be used for other muscle groups, such as the leg.
- Performing pre and post recorded repetitions with the same speed and technique is key to compare centroid frequencies and identify fatigue.