

Tendon Health Monitoring System

Team Name: EcoTendon

Student Names: Sam Greenaway, Shaocheng Wu, Enzo Nate, Tom Avery, Aditi Edlabadkar

Faculty Advisor: Prof. Eric Holloway, Dr. Junfei Li (ME), Prof. Deva Chan(BME)



Left to right: Tom, Enzo, Leno, Aditi and Sam

Abstract: The objective of this project was to develop an accessible tool that detects tendon overuse and supports injury prevention/recovery for athletes and general users. We designed a **wearable ultrasound system** that monitors tendon mechanics and reduces the risk of Achilles injuries. The system enables noninvasive tendon monitoring before and after activity. Overall, this project combines biomechanics, ultrasound signal processing, and wearable device design, laying out the groundwork for a future AI-enabled tendon-health monitoring platform.

Background/Customer Input

Achilles injuries are one of the most common injuries in the US with an estimated **4,500-6,600 ruptures** per year. The Recovery time ranges from **4-18 months** and costs from **\$6K-\$25K**.

Professional Input

Dr. Carly Day,
Head Team Physician
Purdue University

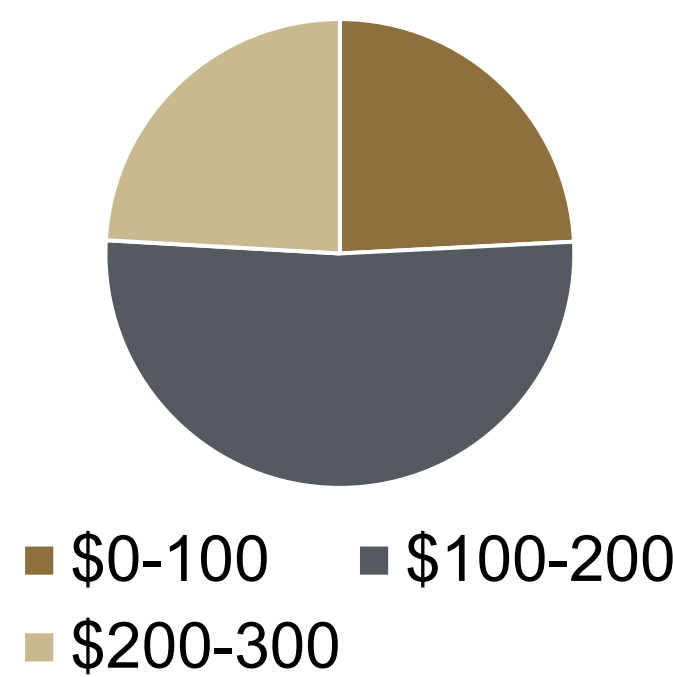
- **Portability** and **Accuracy**.
- **Cost effective** and **easy to use**.

Dr. Dan Cushman,
Professor, School of
Medicine, University
of Utah

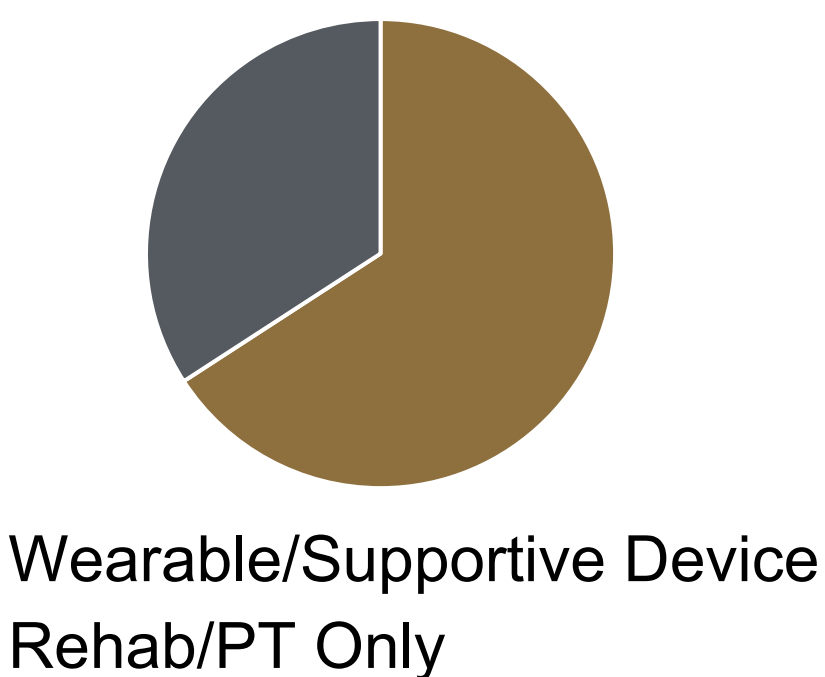
- Ease of **Use** and **Portability**.
- Price is **NOT** the **No.1 concern** if data is accurate

Non-Professional Athletes Survey (n=58, basketball/soccer)

Ideal Cost



Recovery Preference



Competition/Market

Wearable devices in Sports Medicine have a projected market of **\$91 billion by 2034**. Little to no products for tendon health.

Competitive Products In **General** Tendon Health Monitoring



Handheld
Dynamometer

\$400 -
\$2000

Affordable, portable
operator dependent,
limited data.



MyotonPRO
palpation
device

\$6400

Quantitative, Portable,
but superficial tissues
only + high cost.

Significant gaps in the market that can be addressed by a data driven, low-cost product. Making a wearable product is innovative.

Engineering Requirements



Low Cost (Prototype ~\$700)



Wearable + Portable (< 3lbs and easy to wear)



No Additional risk of Injury



Accurate Sensor Positioning

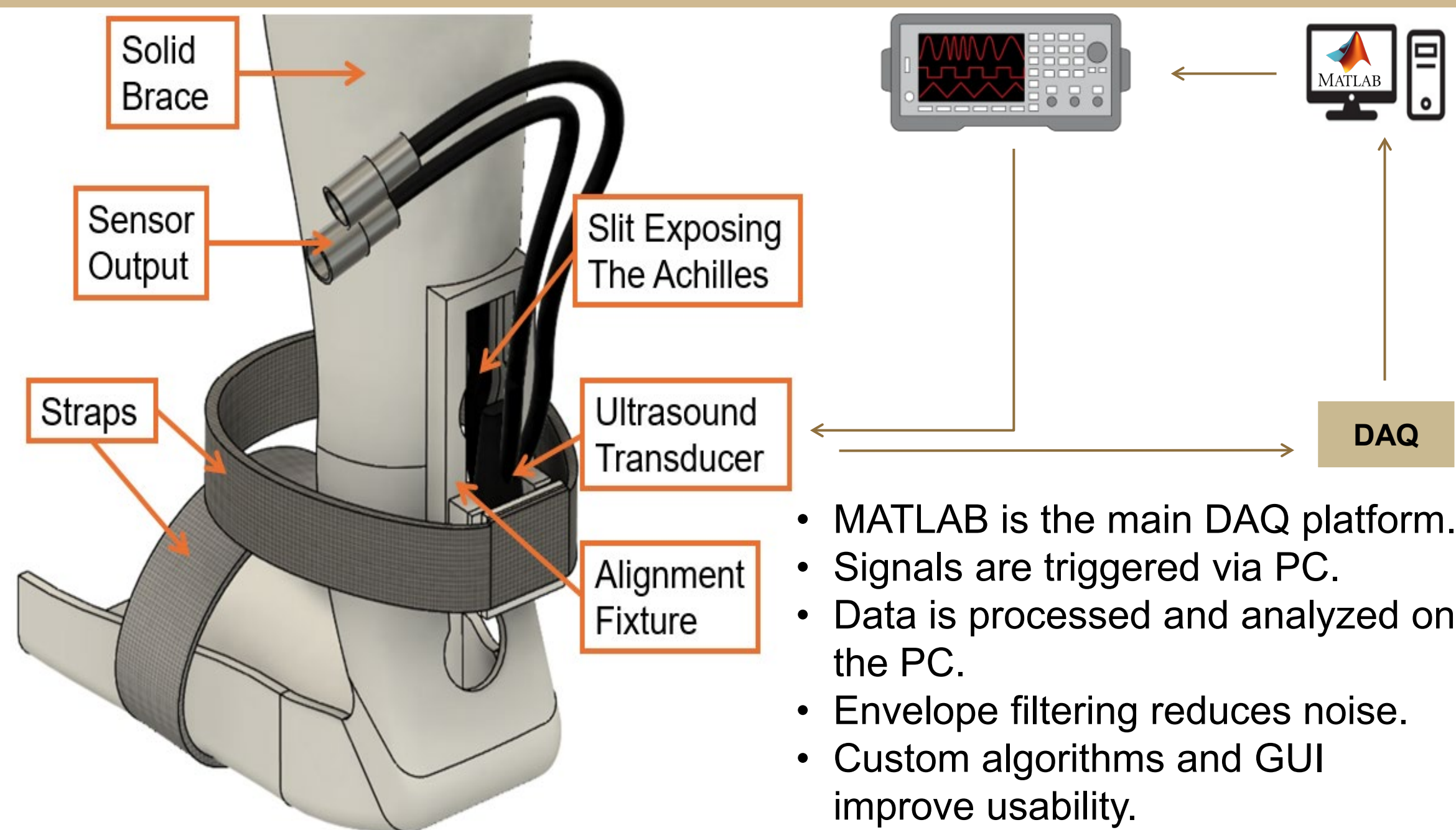


Accurate Tendon Assessment

Value Proposition

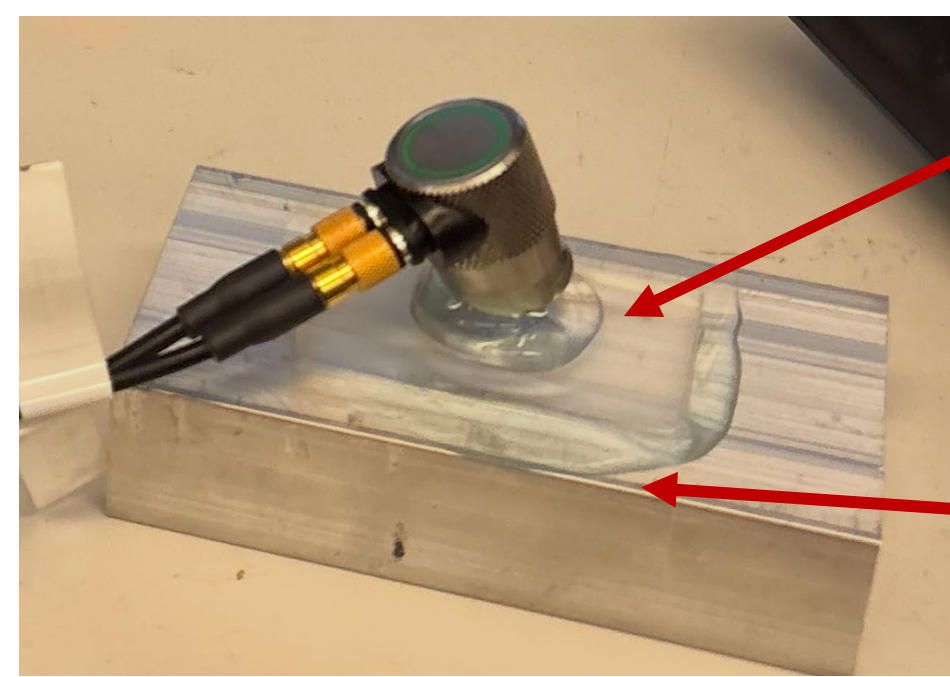
Product offers more actionable insights into tendon health at a **lower cost** than competitors, with a **user-friendly** design that makes monitoring **simple and effective**.

Wearable Sensing Architecture



Validation Testing & Iteration

- All engineering requirements were validated through testing.
- For example, accurate tendon assessment was validated by testing the minimum distance the ultrasound transducer can detect.



Mock Skin
& Tissue
Material

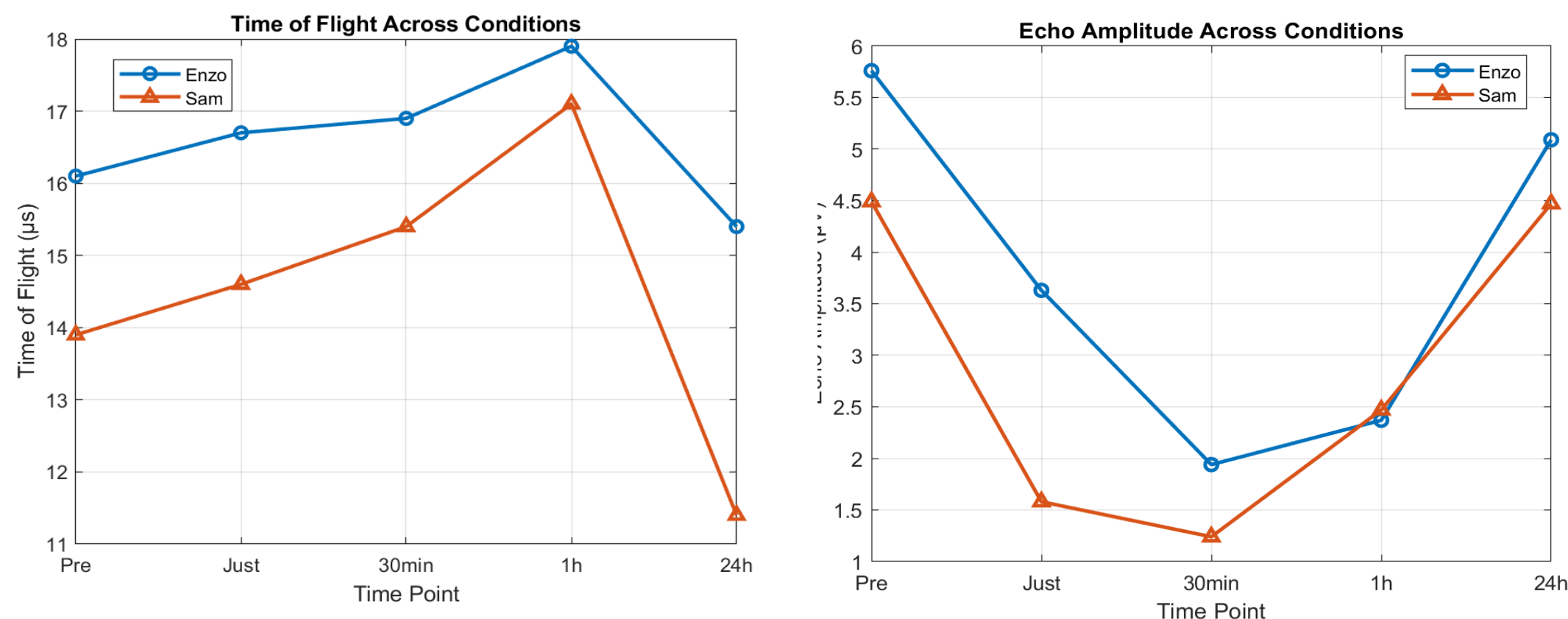
Mock Bone
Material

Iteration and
Testing Results

Tendon Response and Recovery Insights

Acute Tendon Loading and Recovery Response

Our data suggest that bone-echo-based Time of Flight (TOF) and Echo amplitude can sensitively capture acute, reversible, changes in Achilles tendon properties following exercise in 24 hours.



- TOF **increased** immediately after exercise, indicating reduced sound speed consistent with acute tendon stiffening and early fatigue. TOF gradually recovers by 24 h.
- Echo amplitude **decreased** post-exercise, suggesting increased attenuation caused by microstructural disruption or swelling in the tendon-bone path. Eco amplitude graduate **recovers** from post-exercise 1h.

Tendon Health Index

We introduce two simple, ultrasound-derived metrics to quantify tendon loading and recovery and these metrics allow simple, interpretable tracking of **tendon stress and recovery capacity** using a wearable ultrasound system.

$$Workout\ Stress\ Index(WSI) = \frac{T_{post} - T_{pre}}{T_{pre}}$$



Enzo: 0.11 < 0.2



Sam: 0.15 < 0.17 < 0.2

$$Recovery\ Index(RI) = \frac{A_{24h} - A_{pre}}{A_{pre}}$$

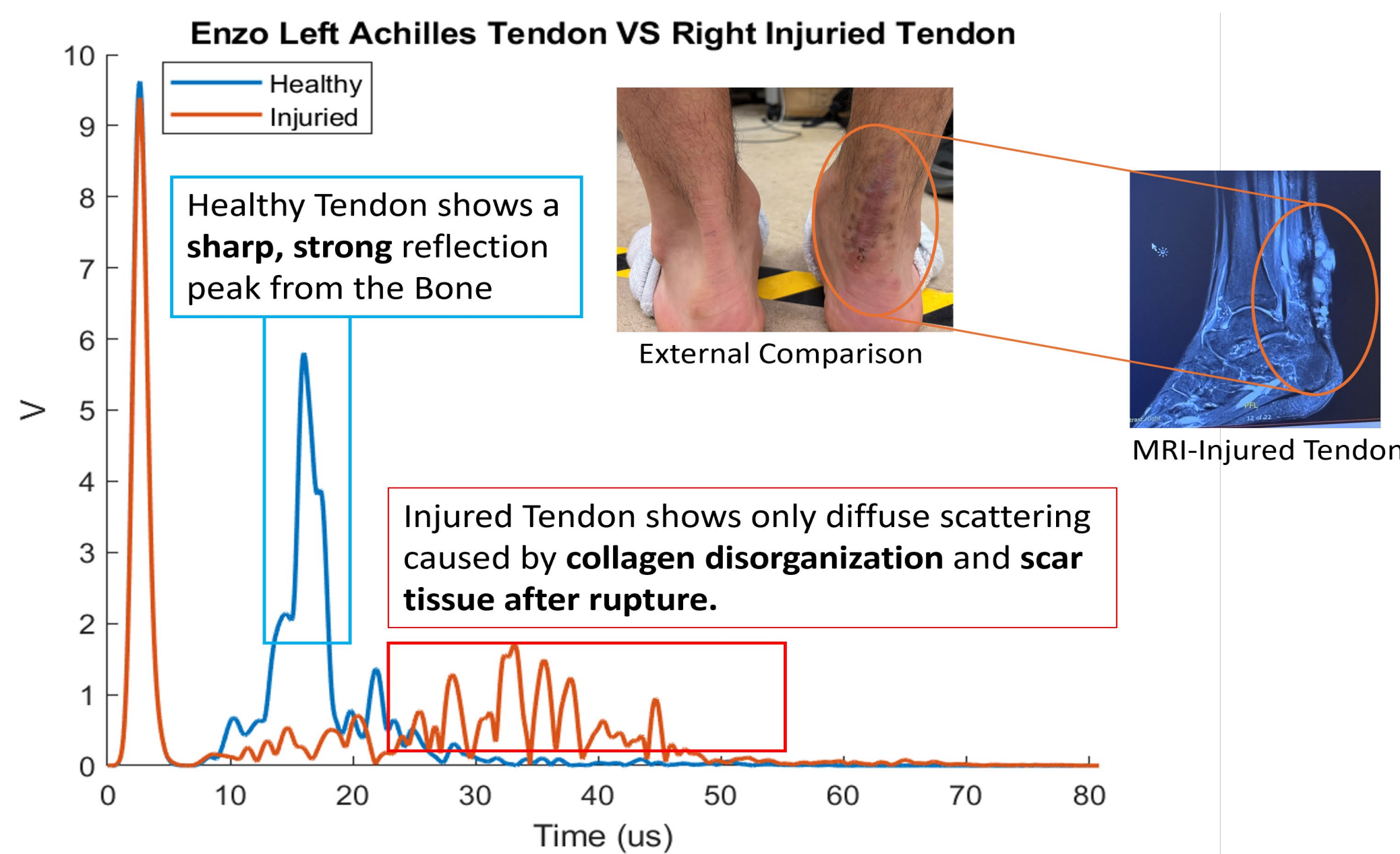


Enzo: 0.01 < 0.095 < 0.1



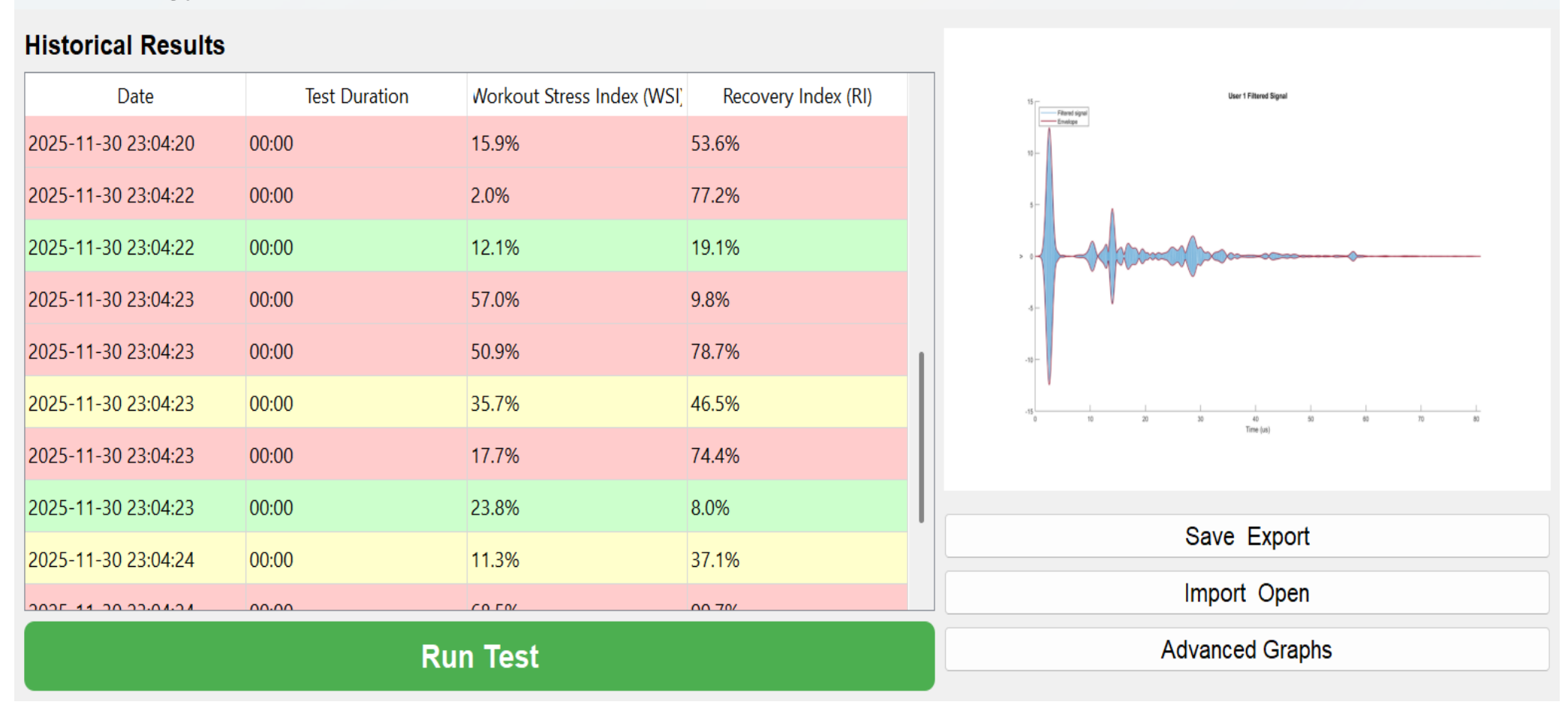
Sam: 0.004 < 0.01

Rehabilitation Progress

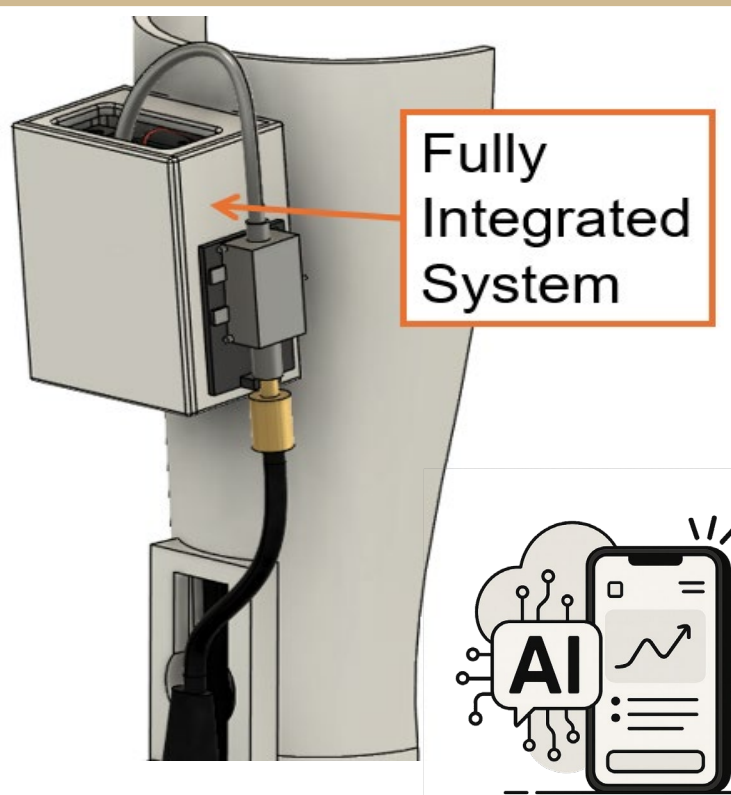


The sensor can detect **structural healing** changes. Has potential as a **real-time rehabilitation** tool.

Integrated GUI System



Future Innovation



- Fully-Integrated system with (DAQ, Function Generator etc.) without external connections.
- Personalized brace for easy carry-on during activities.
- Provide real-time results and actionable data to the user though AI and Machine Learning Tools.

Acknowledgments

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Alicia Schwipps - Athletico Physical Therapy, West Lafayette

Jeff Stein, PT, ATC, DPT, Director of Physical Therapy, Purdue University

Ultrasound Response for early Achilles Injury prevention

