School of Biomedical Engineering, Science & Health Systems

Measuring Changes in Passive Muscle Stiffness Following Activity

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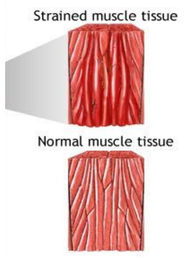
Wants

- Ensure safe physical activity by determining:
  - Readiness for competition/intense activity
  - Necessity of further therapy
- Immediate results
- Device used for multiple muscle groups
- Optimize player performance
  - Feel able-bodied for competitive sports
  - Reduce mental anxiety

Need

- **Passive muscle stiffness** - loss or reduction in joint's range of motion (ROM) during physical activity
- Use Elastic Modulus rather than stiffness to analyze passive muscle stiffness
  - Can distinguish between healthy vs. not healthy tissue
  - Measuring the **target muscle** → more **accurate evaluation**
- Stiff muscle = decrease in ROM = decrease in athletic performance[1]



High vs Low Elastic Modulus Muscle Tissue

Existing Solutions

Criteria	PEF Device	Myoton	Elastography	Rotational Analysis
Measure Elastic Modulus	✓	✗	✗	✗
Detect deep muscle	✓	✗	✗	✗
Measure an increase in Elastic Modulus after abduction	✓	✗	✗	✗
Measure change in muscle stiffness	✓	✓	✓	✗
Measure various muscle groups	✓	✗	✓	✓

Customer Fears

- Fear of injury
  - Exacerbation of injury
  - Fear of doing permanent damage
  - Returning from injury too soon
- Fear that accurate range of motion analysis cannot be gauged for multi-sport athletes
- Test could involve cumbersome equipment, be inconvenient, slow, and costly

Product Features

Piezoelectric Finger (PEF)

- Based on the reversible **Piezoelectric effect[2]:**
  - Mechanical deformation → charge accumulation OR charge accumulation → mechanical deformation
- Measures **Elastic Modulus** by measuring changes in *induced voltage with and without tissue[8]*
- Utilize PEF with 6mm widths to measure Elastic Modulus and detect changes in passive muscle stiffness

Solution Model

Electric current applied to driving PZT layer

↓

Driving PZT layer deflects downwards

↓

Sensing PZT layer deflects downwards

↓

Voltage induced in sensing PZT layer

$$E = \frac{1}{2}\left(\frac{\pi}{A}\right)^{\frac{1}{2}}(1-\vartheta^2)\frac{K\,(V_{in,0}-V_{in})}{V_{in}}$$

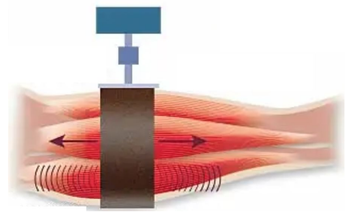
- ***E = elastic modulus of tissue***
- *A = surface area of probe tip (36mm^2);*
- *ν = Poisson's ratio of tissue (0.5);*
- *K = spring constant of PEF (143 N/m);*
- ***$V_{in,0}$** = voltage induced without tissue;*
- ***V_{in}** = voltage induced with tissue[6]*

Product Benefits

- Quantitatively analyze passive muscle stiffness using Elastic Modulus
- Measuring target muscle → more accurate evaluation
- Allow athletic trainers and physical therapists to assess patients
  - Help players perform more optimally
  - Determine specific therapy for rehabilitation
- Prevent the overuse of muscles
- Lead poisoning will be prevented by housing
- Repeatable use of device can lead to minimal pollution
- User-friendly

Product Experience

- Near-immediate machine results
- Pain-free evaluation of muscle stiffness
- Can utilize on oneself if conducted properly
  - Small learning curve
  - Commercial product will have a user-friendly design
  - Easily interpretable results
- High satisfaction with accuracy of the results



References: **[1]"Measuring Range of Motion," us.humankinetics.com. [2] Johnson Electric,The Piezoelectric Effect. *Nanomotion*. [3] "Elastography" Mayo Clinic. [4] "Technology." *Myoton*, www.myoton.com/technology/. [5] Shankar, Nachiket, et al., 2014. [6] W. Shih, 2013.**

Acknowledgements

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