

MuscleRehab: Improving Unsupervised Physical Rehabilitation by Monitoring and Visualizing Muscle Engagement

Junyi Zhu, Yuxuan Lei, Aashini Shah, Gila Schein, Hamid Ghaednia, Joseph H. Schwab, Casper Harteveld, Stefanie Mueller

• WHO's Call for Action: Scale Up Rehabilitation



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- Physical Therapist's Essential Tasks
 - Determining Patient's Condition
 - Creating & Guiding Training Tasks
 - Correcting Exercise Mistakes and Evaluating



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MuscleRehab Walkthrough

MuscleRehab

- Optical Motion Capture System
- Wearable EIT Sensing Device
- Rehabilitation User Interface







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EIT 3D Volumetric Configuration -

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Wearable EIT Device

EIT 3D Volumetric Configuration

Quadriceps Sartorius Adductors Hamstring

EIT 3D Volumetric Configuration

Wearable EIT Sensing Device



Muscle Engagement Calculation

Threshold of Engagement = |0.5|EIT Data Array = {0.56, -0.41, 0.22,-0.69}





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Muscle Engagement Visualization









TRAINING REGIMEN

LEPT				
~	RIGHT			
FRONT LUNGE	FRONT LUNGE			
SEATED KNEE	SEATED KNEE			
STRAIGHT LEG RAISE	STRAIGHT LEG RAISE			
TERMINAL KNEE EXT.	TERMINAL KNEE EXT.			
SINGLE LEG SQUATS	SINGLE LEG SQUATS			
BRIDGES	BRIDGES			
STANDING FIRE HYD.	STANDING FIRE HYD.			
THE LEG DEADLIFT	SINGLE LEG DEADLIFT			
SINGLE STANDING KNEE				
SIT STAND				



FRONT LUNGE

~ **_**)))

1. Stand tall with feet hip-width apart. Engage your core.

Take a big step forward with right leg. Start to shift your weight forward so heel hits the floor first.

OHELP

~

3. Lower your body until right thigh is parallel to the floor and right shin is vertical. It's OK if knee shifts forward a little as long as it doesn't go past right toe. If mobility allows, lightly tap left knee to the floor while keeping weight in right heel.

4. Press into right heel to drive back up to starting position.

5. Repeat on the other side.

CONTINUE TO RIGHT

User Study #1

• Hypothesis: real-time muscle visualization results in higher muscle engagement accuracy

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- Participants: 10 participants (4 female, 6 male)
- Conditions: Motion Only vs. Motion + Muscle Vis.

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- Participants: 10 participants (4 female, 6 male)
- Conditions: Motion Only vs. Motion + Muscle Vis.
- Exercises: Total Knee Arthroplasty (TKA) rehabilitation protocol
- Measuring Metrics



Front Lunge



Terminal Knee Extension



Standing Knee Bend



Single Leg Squat



Seated Knee



Sit to Stand



Single Leg Deadlift



Standing Fire Hydrant



Straight Leg Raise Side



Single Leg Bridge

Front Lunge

0

15

P6

0

10





Motion Only

P1

18

Motion + Muscle Vis.

0

0

Exercise Type	Motion	Motion+Muscle Vis.	p-value
Front Lunge	59.13%	72.02%	0.099
Standing Knee Bend	44.92%	61.58%	0.064
Seated Knee	47.51%	59.52%	0.278
Single Leg Deadlift	41.16%	72.42%	0.010
Straight Leg Raise Side	48.00%	67.89%	0.041
Terminal Knee Extension	54.82%	54.84%	0.998
Single Leg Squat	55.58%	53.31%	0.779
Sit to Stand	66.31%	36.01%	0.015
Standing Fire Hydrant	54.29%	76.07%	0.069
Single Leg Bridge	28.61%	96.55%	0.002
Average Accuracy	50.03%	65.02%	0.024

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- Some Outliers

User Study #2

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- Participants: 6 licensed physical therapists (2 female, 4 male)

- Hypothesis: muscle engagement data assists remote post-rehabilitation analysis closer to on-site analysis
- Participants: 6 licensed physical therapists (2 female, 4 male)
- Conditions: Motion Only vs. Motion + Muscle Vis. (Recorded Videos)
- Compared Ratings to On-site Physical Therapist Analysis

Exercise Type	Motion Only	Motion + Muscle Vis.
Front Lunge	1.36	0.44
Standing Knee Bend	0.82	0.33
Seated Knee	0.13	0.69
Single Leg Deadlift	1.34	1.61
Straight Leg Raise Side	2.69	1.98
Terminal Knee Extension	2.45	0.16
Single Leg Squat	4.25	0.56
Sit to Stand	0.74	1.11
Standing Fire Hydrant	2.06	0.89
Single Leg Bridge	0.35	0.55
Average Deviation	1.62	0.83

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Closer to on-site PT with
Muscle Vis.

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	Straight Leg Raise Side	2.69	1.98	•	with the Detient
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Sit to Stand	0.74	1.11	•	Integrating Exercise Motivators
Standing Fire Hydrant	2.06	0.89		
Single Leg Bridge	0.35	0.55	•	Additional View Points
Average Deviation	1.62	0.83	_	

Implementation

Electrical Impedance Tomography (EIT)



Electrical Impedance Tomography (EIT)





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$$J = \sigma \nabla \varphi$$

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$$\nabla \cdot J = I$$

$$\checkmark$$

$$\nabla \cdot \sigma \nabla \phi = 0.$$











Display Modalities









- Display Modalities
- OptiTrack vs. Commercial Tracking System



- Display Modalities
- OptiTrack vs. Commercial Tracking System
- Multiple EIT devices



- Display Modalities
- OptiTrack vs. Commercial Tracking System
- Multiple EIT devices
- Additional Feedback



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