Collaborative Research: NRI: INT: Customizable Lower-Limb Wearable Robot using Soft-Wearable Sensor to Assist Occupational Workers

Myunghee Kim (PI, UIC), Heejin Jeong (Co-PI, UIC), W. Hong Yeo (PI, Georgia Tech)

NSF-NRI, NIOSH
Award ID#: 2024863, 2024742

Goal: Personalization in lower-limb assistive wearable robots using human-in-the-loop (HIL) optimization to reduce the physical effort in intensive activities, thereby reducing injury.

Challenges

1) Inaccurate, slow physical effort estimation.
2) Error-prone, burdensome biofeedback sensors.
3) Evaluation for intensive activities.

Aim 1. Fast HIL optimization

- **The importance of personalized assistance for squatting was tested**
  - Developed fast model-free, phase-plane based metabolic cost estimation method (Fig. 1B) [1].
  - Implemented a squat assistance controller in a robotic ankle exoskeleton (Fig. 1 AD) [2].
  - Conducted human-in-the-loop optimization (Fig. 1).
  - Optimized assistance reduced metabolic cost of squatting (Fig. 2).

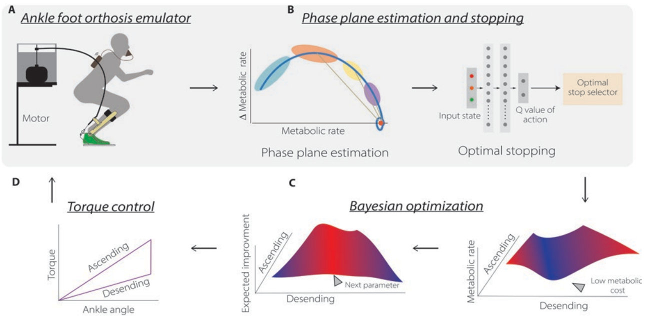

Fig. 1 Human-in-the-loop (HIL) optimization for squatting.

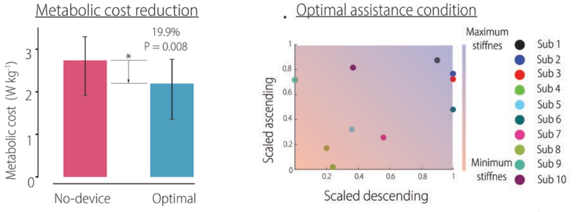

Fig. 2 The optimized assistance reduced the metabolic cost of squatting (left). Each participant presented a different optimal assistance parameter set (right).

- **ECG metric can be an alternative measure**

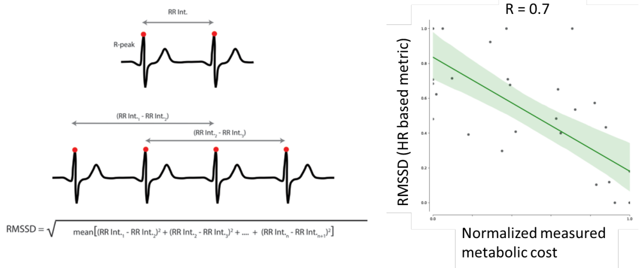

Fig. 3 RMSSD (left), an ECG measure, presented a high correlation to the metabolic cost of squatting (right).

- **Metric using EMG can be an alternative**
  - The optimized assistance reduced activities of muscle synergies (muscle coordination patterns) [3].

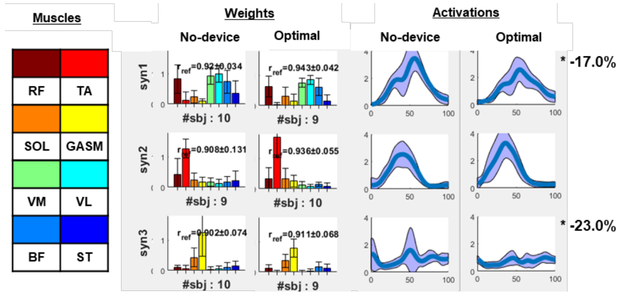

Fig. 4 Muscle coordination and activation patterns during squatting for the no-device and optimized assistance conditions.

- **A pressure sensor can be a potential measure**

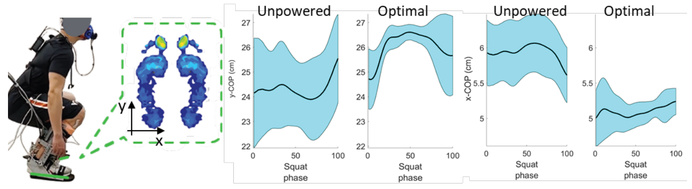

Fig. 5 Personalized assistance appears to change CoP variability [4].

Aim 2: Soft wearable electronics

Fig. 6 Bulky Commercial calorimetric devices & soft wearable electronics (red circle) [5].

Aim 3: Seamless integration & evaluation

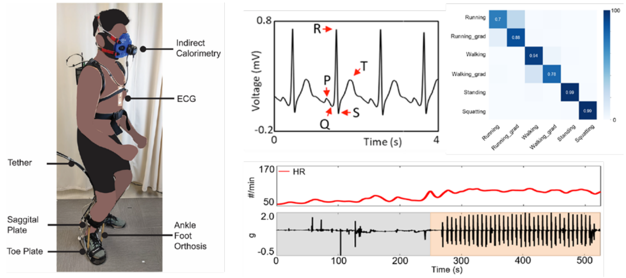

Fig. 7 AFO and biopatch with calorimetry mask (left) and bio-signal from soft wearable electronics (right) [5].

Impact: Science & Technology, Applications / Education

- Efficient physical effort estimation for customizing assistance to assist workers.
- Integrates research & education via projects with improved infrastructure
- Wireless, soft wearable electronics, applicable for diagnosis and monitoring.

References

[1] Kantharaju and Kim, *under review.*
[2] Kantharaju et. al., *under review.*
[3] Jeong et.al., *in preparation.*
[4] Ramadurai et.al., *under review.*
[5] Kim et. al, *in preparation.*