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

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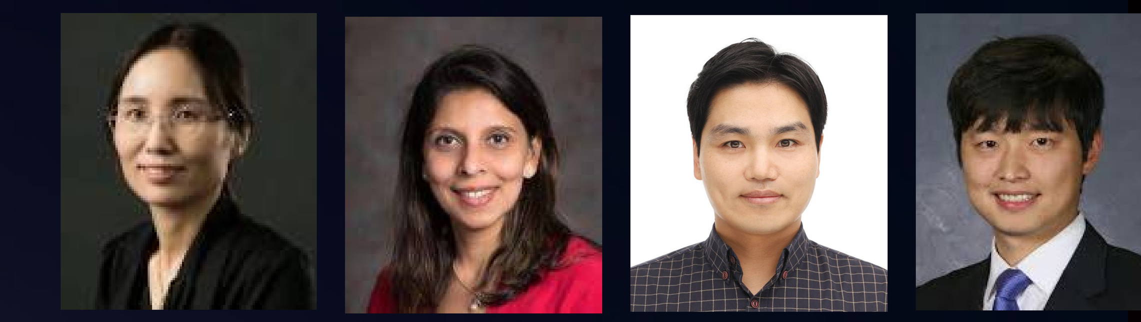

Goal: Personalization in lower-limb assistive wearable robots using human-in-the-loop (HIL) optimization to reduce the physical effort in intensive activities, thereby reducing injury.

Challenges

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

Aim 1. Fast HIL optimization

- **Personalized squat assistance can reduce user's physical exertion significantly (Fig. 1, 2)**
  - Used fast data-driven, phase-plane based metabolic cost estimation method (Fig. 1B) [1].
  - Implemented a HIL optimization squat assistance method in a robotic ankle exoskeleton (Fig. 1A-D) [2].
  - Person specific assistance (Fig. 1E) reduced metabolic cost (Fig. 1F) [2], muscle synergy activities (Fig. 2A) [3], changed CoP (Fig. 2B) [4], and increased RMSSD (Fig. 3E) [5].

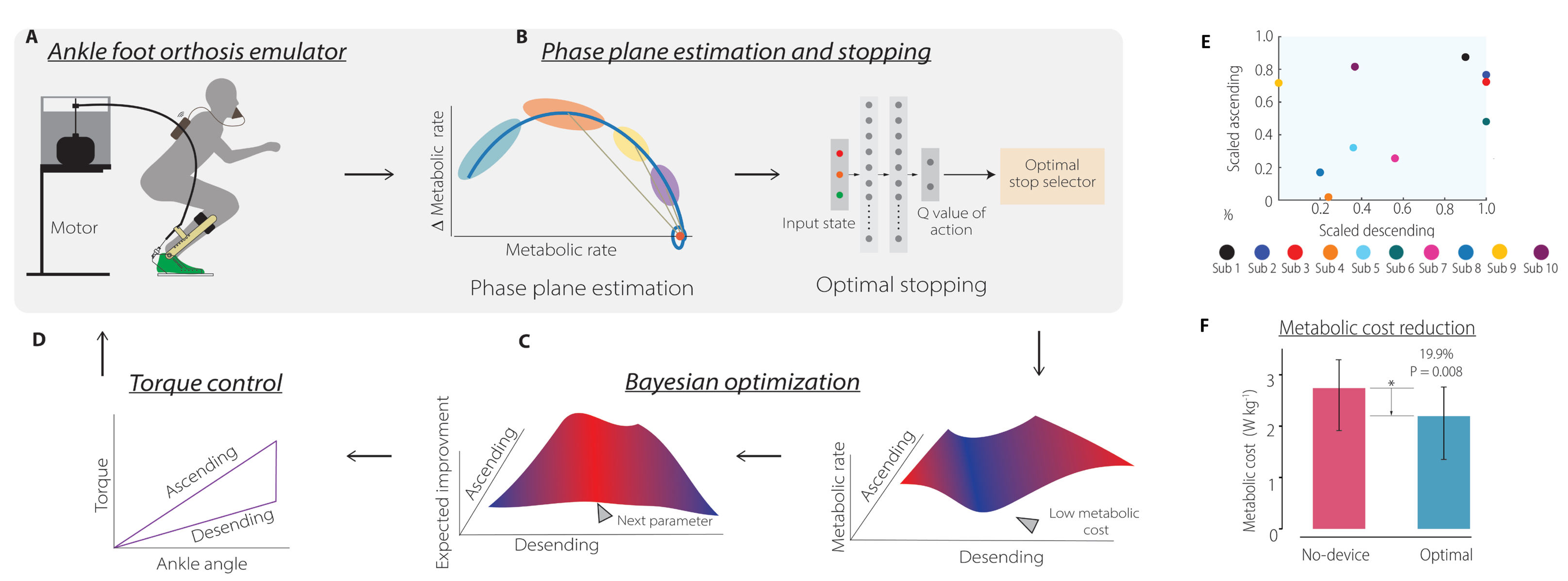

Fig. 1 Human-in-the-loop (HIL) optimization for squatting (A-D) identified person-specific parameters (E) and reduced effort (F) [2].

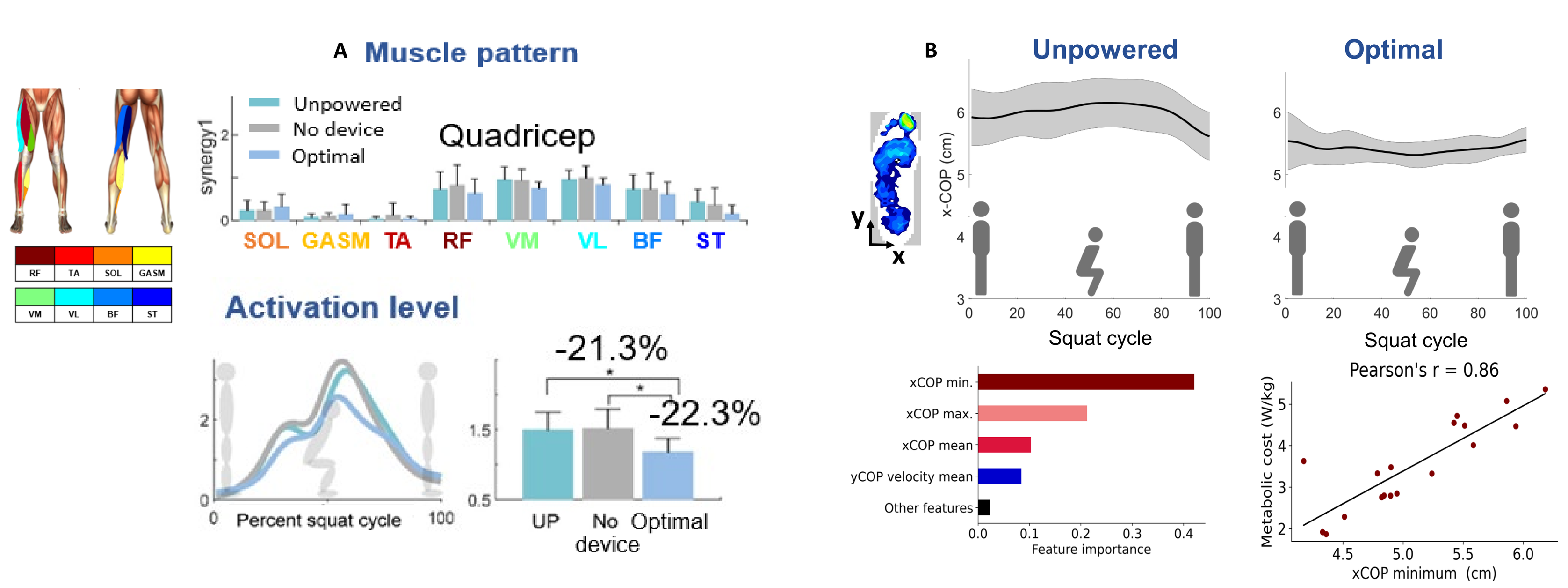

Fig. 2 The optimized assistance reduced the quadricep dominant muscle synergy and RF muscle activity (A) [3] and mainly influenced x-Center of Pressure (CoP) pattern (B) [4].

Aim 2: Soft wearable electronics

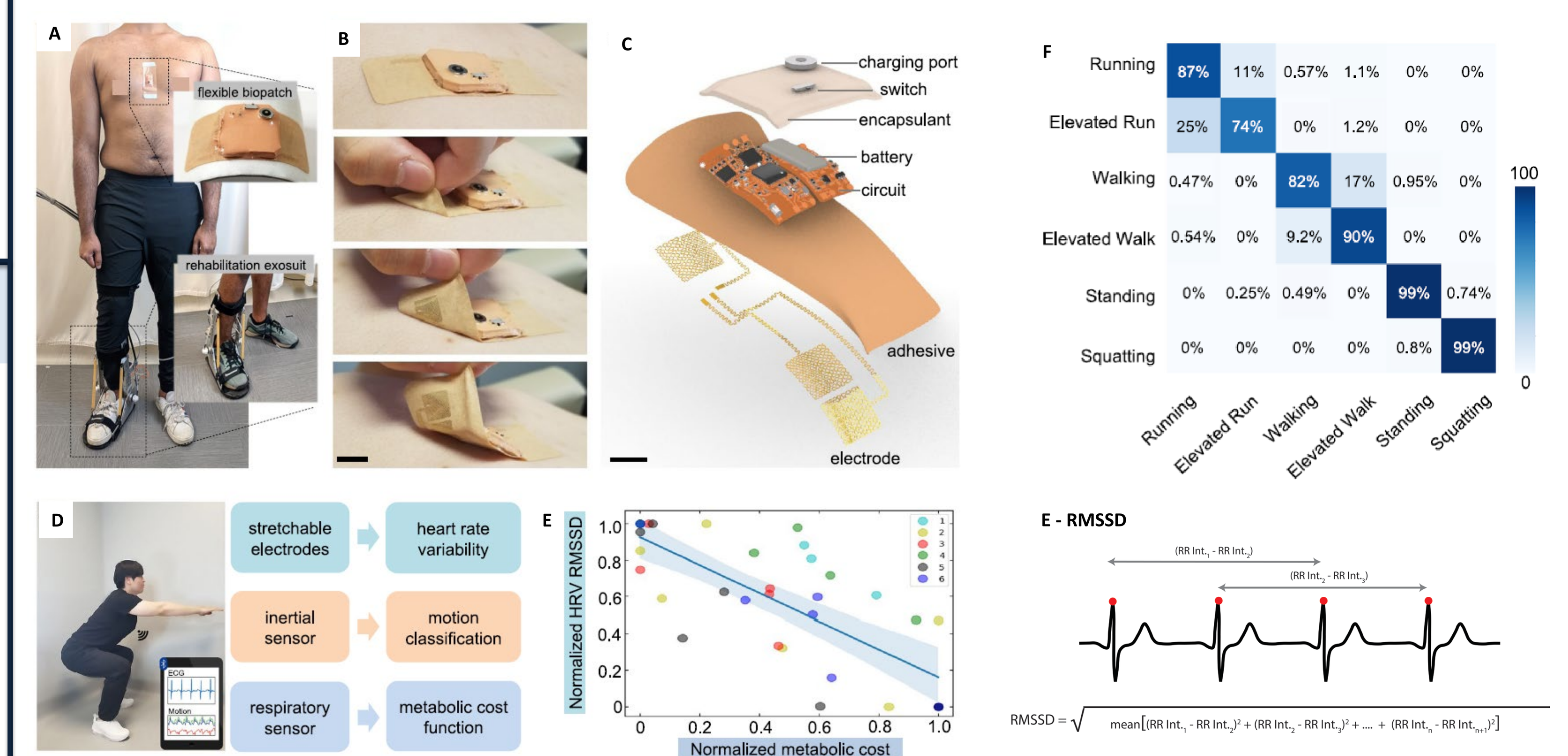

Fig. 3 Soft devices (A-C) estimate physical effort (E) and to detect activities (F) [5].

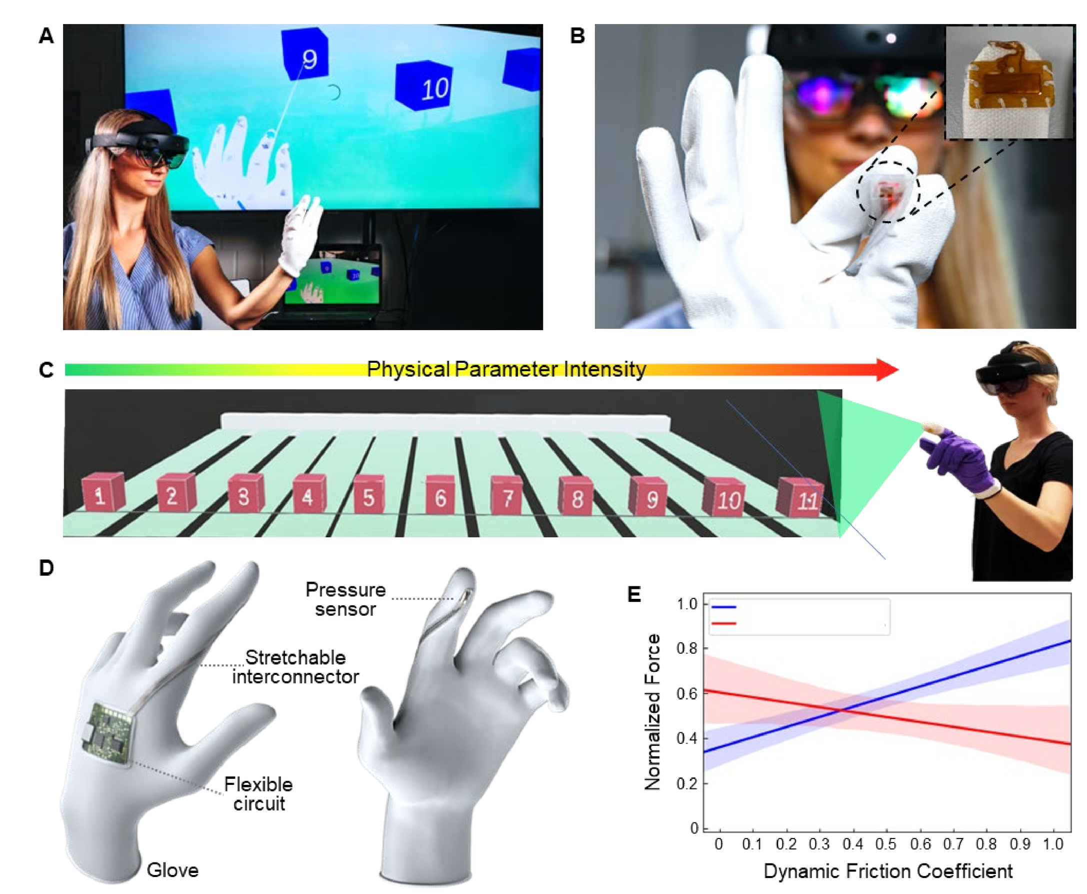

Fig. 4 An mixed-reality soft wearable biosensing glove for manipulating objects (A-C), including pressure sensors and stretchable interconnectors (D) for the pinching measure study (E), showing the trend as dynamic friction coefficient changes [6].

Aim 3: Seamless integration & evaluation

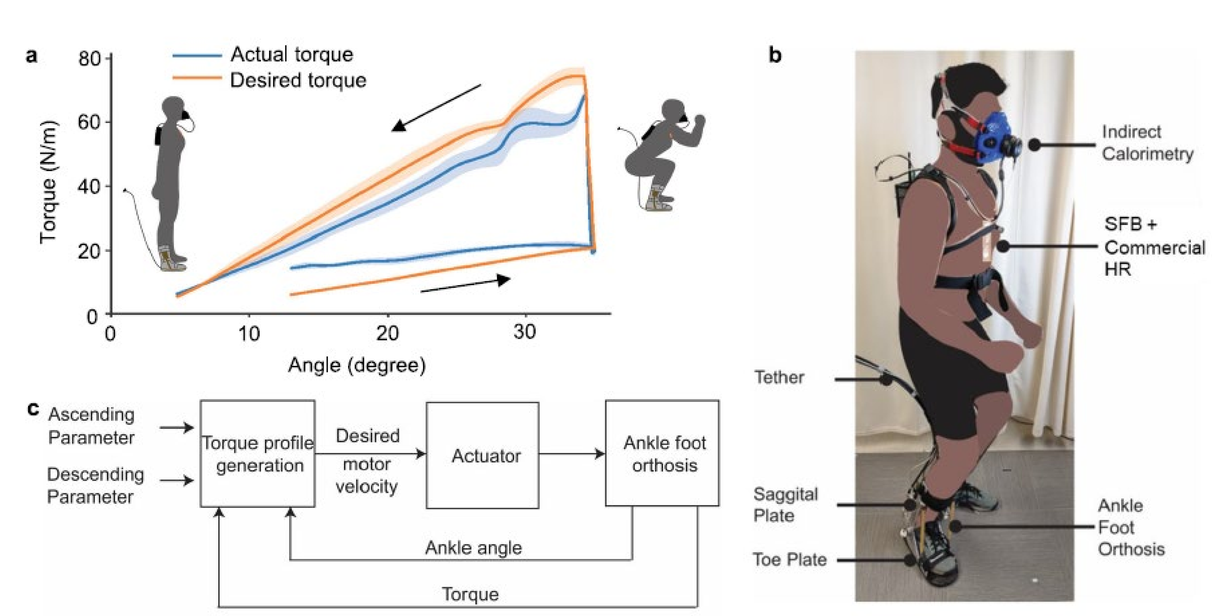

Fig. 5 HIL optimization using ECG sensor – Preliminary study

- **HIL optimization using EMG/ECG sensor – to the wild**

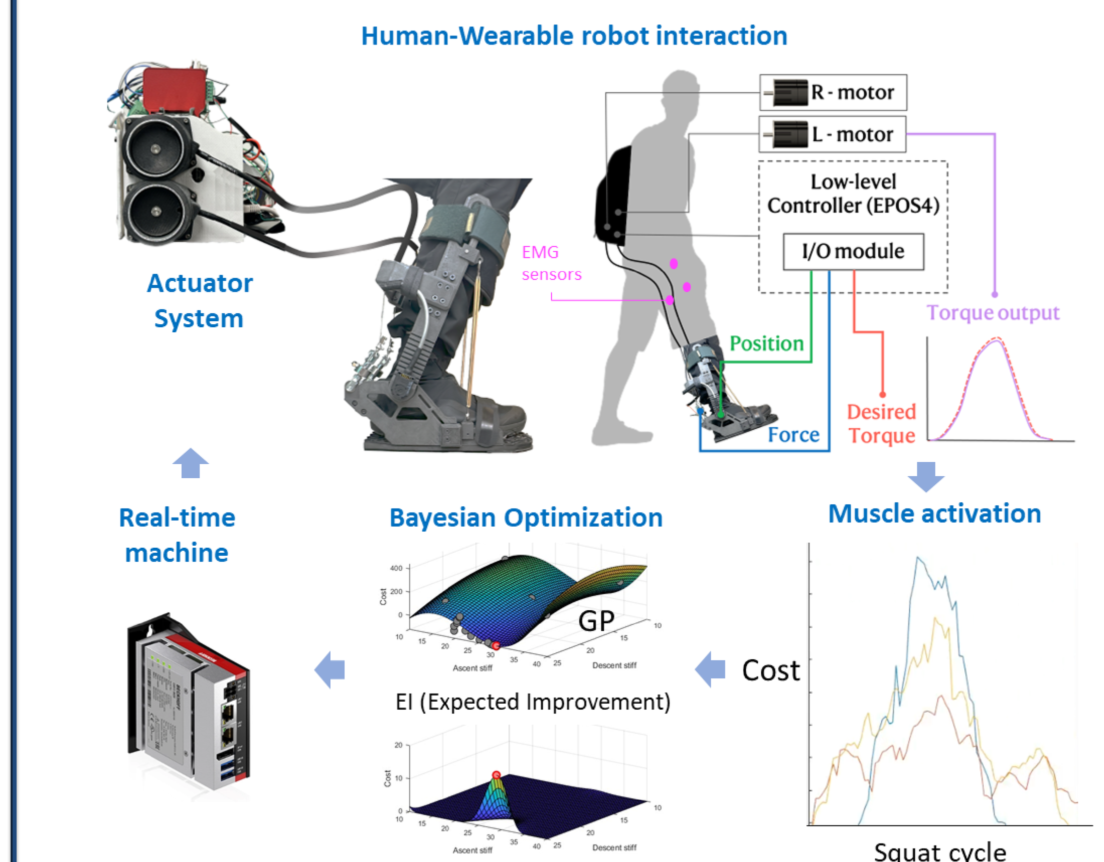

Fig. 6 HIL optimization using a portable actuation system and a modular ankle-foot orthosis [7].

The muscle activity and heart rate can be detected in an app; then used to determine the personalized assistance.

Impact: Science & Technology, Applications / Education

- Efficient physical effort estimation for customizing assistance to assist workers.
- Integrates research & education via projects with improved infrastructure: **Example - Fig. 6**: the modular AFO and portable actuation system.
- Wireless, soft wearable electronics, applicable for diagnosis and monitoring.
- Outreach: the project outcome was used
  Fig. 7A: for health science guest lecture + lab tour
  Fig. 7B: for Engineering open house
  Fig. 7C: for K-12 hands-on experience

Fig. 7 Outreach

References

[1] Kantharaju and Kim, 2022, *ACCESS*.
[2] Kantharaju et. al., 2022, *TNSRE*.
[3] Jeong et.al., 2023, *Sci. Rep.*
[4] Ramadurai et.al., 2023, *Front. Robot. AI.*.
[5] Kim et. al, 2023, *npj Flexible Elect.*.
[6] Kim et. al , 2023, *Biosens. Bioelectronics*.
[7] Sanz-Pena et al., in review

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