Effect of Timing of Hip Extension Assistance with IMU-based Iterative Control during Loaded Walking with a Soft Exosuit

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MOTIVATION

- **Walking variability** in joint kinematics and kinetics makes it harder for same effective external assistive force to provide metabolic benefits to all wearer.
- Understanding the **effects of different hip assistive profiles** is a fundamentalT step of designing assistive device that can provide higher metabolic benefits.
- Limited literature with studies **exploring the effects of timing and magnitude of assistance** on hip joint.

HYPOTHESIS

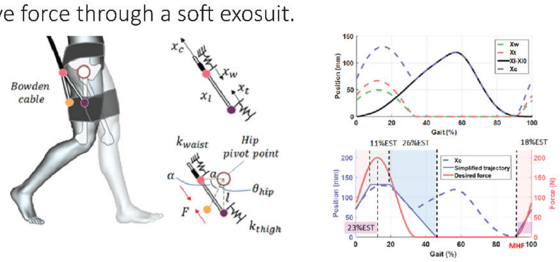
- Proposed controller can **adapt different kinematics and kinetics and provide consistent hip joint assistance.**
- **Onset timing and peak force timing** can regulate the amount of positive mechanical power delivered to the hip joint which is related to **metabolic cost of walking.**

AIM

- **Model soft exosuit** to determine how to appropriate apply the desired assistive force through a soft exosuit
- **Design and validate the performance of IMU-based iterative** control across different subjects.
- **Investigate the effect of onset and peak timings** between hip assistive profiles by means of a soft exosuit.ᵀ

MODELING

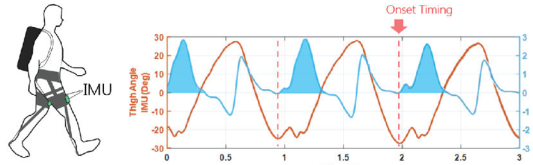
- Model soft exosuit to determine how to appropriate apply the desired assistive force through a soft exosuit.



CONTROLLER

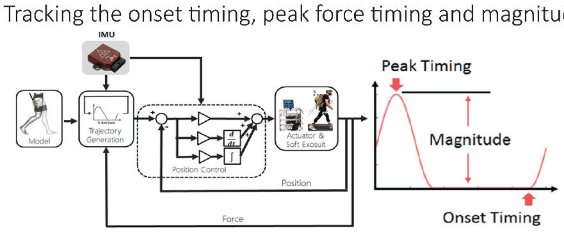
Timing detection

- Detect the onset timing with maximum thigh flexion point from IMU



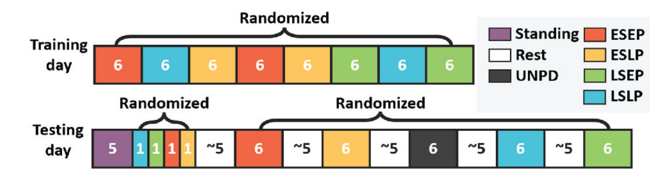
Force tracking

- Generate position trajectory profile based on a step-by-step force feedback
- Tracking the onset timing, peak force timing and magnitude



METHOD

- Eight male healthy participants (age 29.8 ± 5.0 yr., weight 82.6 ± 5.8 kg, height 1.79 ± 0.05 m, mean ± SD)
- A baseline condition: **23 kg loaded walking** on treadmill at **1.5 m/s**
Four conditions: **early-start-early-peak (ESEP), early-start-late-peak (ESLP), late-start-early-peak (LSEP), late-start-late-peak (LSLP).**
- Measurements: metabolic cost, kinematic data, ground reaction force, electromyographic signal (EMG).



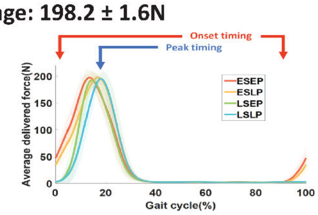
RESULT

Force tracking performance

- Peak timing:
Target: 23%
Average: 22.7 ± 0.6%
- Peak magnitude:
Target: 200N
Average: 198.2 ± 1.6N

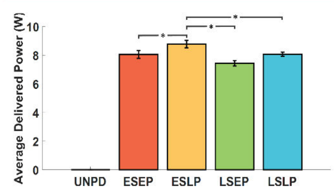
Different assistive force profiles:

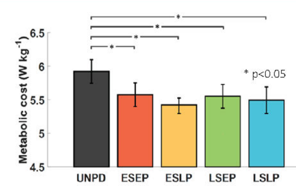
- Onset timing (90%, 0%)
- Peak timing (13%, 17%)
- Peak force 200N



Delivered positive mechanical power & metabolic reduction:

	ESEP	ESLP	LSEP	LSLP
Delivered positive power (W·kg^{-1})	0.198	0.219	0.185	0.198
Metabolic reduction (%)	5.7	8.5	6.3	7.1





DISCUSSION & CONCLUSION

- Demonstrated IMU-based iterative controller **can deliver robust hip extension assistive profiles** across subjects.
- Different assistive conditions provided insight on how to **manipulate actuation timing to regulate positive mechanical power** to augment human walking
- ESLP provided highest mechanical positive power and highest metabolic reduction, suggesting **that starting the assistance at terminal swing with a later peak force may be the most beneficial strategy.**

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