Assessing personalized FES patterns for gait rehabilitation in a clinical setting

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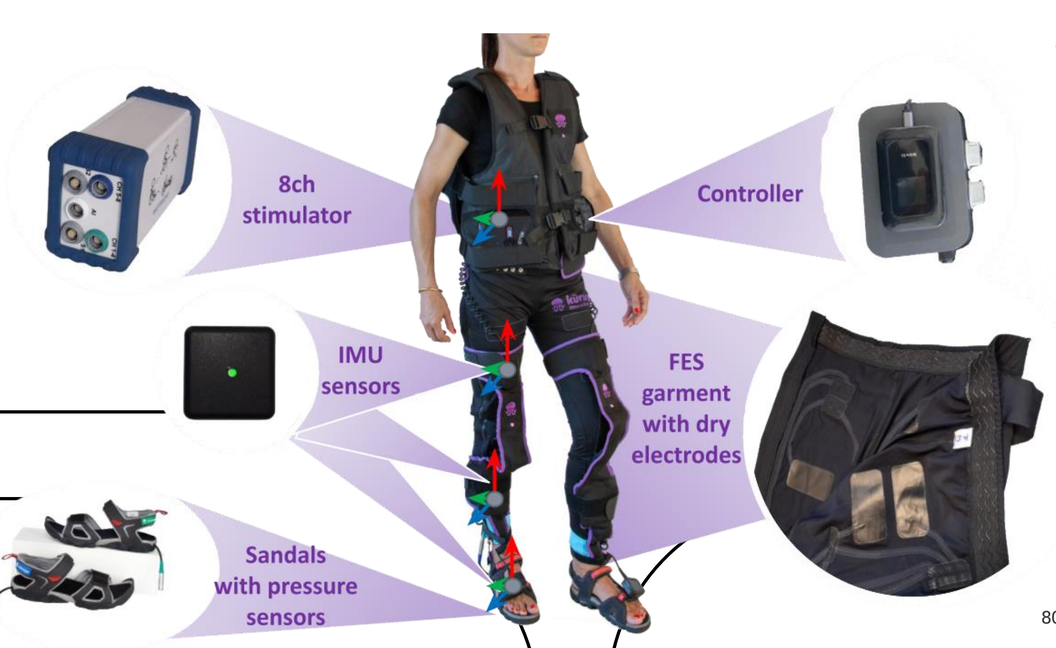
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INTRODUCTION

• **Functional Electrical Stimulation (FES)** is a promising technology for post-stroke gait rehabilitation but faces challenges like increased muscle fatigue compared to volitional motor control, pain, variable responses to stimulation between patients, and the variability of patient clinical profiles. These aspects require personalization of FES therapies.

• **Quantitative gait analysis** is used to characterize healthy or pathological gait by measuring gait domains like pace, rhythm, variability, asymmetry, and postural control through spatiotemporal, kinematic or kinetic metrics.

• FES has been shown to have **orthotic and therapeutic effects** on patient's gait *(Andreopoulou et al. 2024)*, but it is unclear how to characterize if a given FES pattern induces the right orthotic effect to lead to therapeutic gait improvement.



• **This retrospective study evaluates FES stimulation patterns with different personalization degrees** using metrics that assess both immediate orthotic improvements and potential predictors of rehabilitation success, to investigate their capacity to characterize gait enhancements.

METHODS

Population: 3 chronic stroke patients

Comparison of gait on 3 conditions of 1 minute straight walking:

- No stimulation
- Default stimulation patterns
- Personalized stimulation patterns

Stimulation intensities set by physiotherapist for each muscle group prior to conditions

Default stimulation pattern: Gait phase prediction from IMU sensors (using Deep Learning) and default stimulation rules based on gait phase (see below).

Personalized stimulation pattern: Fine-tuned gait phase prediction (using 10 consecutive unstimulated steps of patient data) with physiotherapist-adjusted stimulation parameters (timing and intensity) optimized for each individual patient's walking pattern.

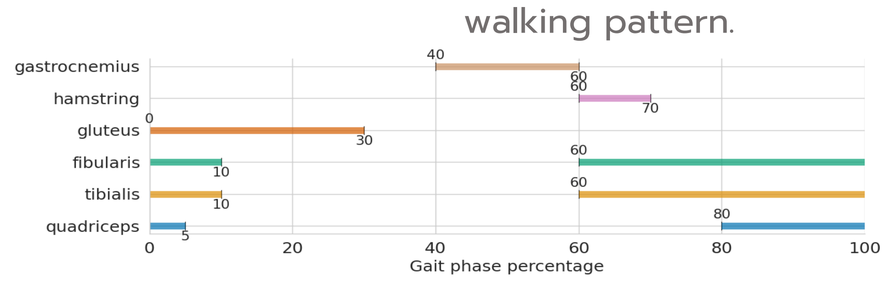
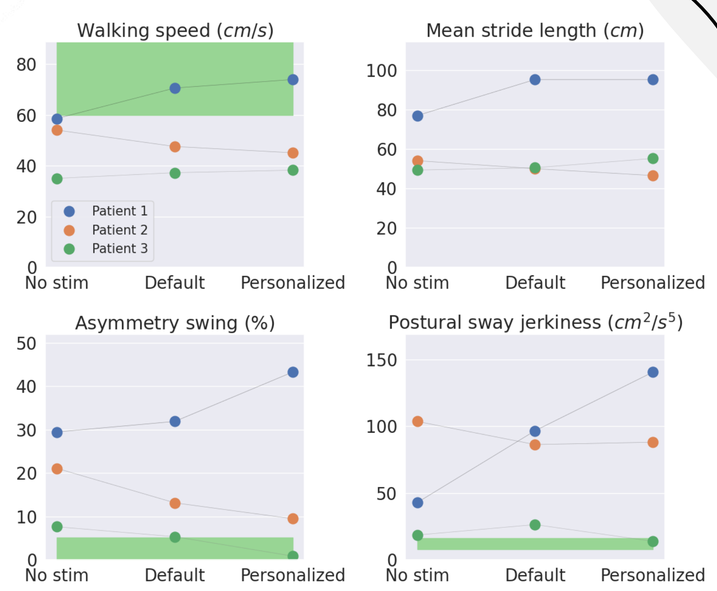


Figure: Default stimulation rules

Metrics: Kinematic: hip, knee and ankle joint angle trajectories, hip range of motion.
Spatiotemporal: walking speed, cadence, stance and swing time and ratio, and double support time and ratio
Postural control: hip movement jerkiness (*Kim et al. 2019*)
Asymmetry: asymmetry in swing phase duration (Rössler *et al. 2024*)

RESULTS



Default stimulation improvements (compared to no stimulation): walking speed (+2.59cm/s), stride length (+5.16cm), and asymmetry (-2.6%)

Personalized stimulation improvements (compared to default stimulation):

- walking speed (+0.63cm/s) and hip range of motion (+3.44°, one patient), kinematic improvements
- patient-specific improvements in different metrics: some patients showing better asymmetry and postural control while another demonstrated increased walking speed.

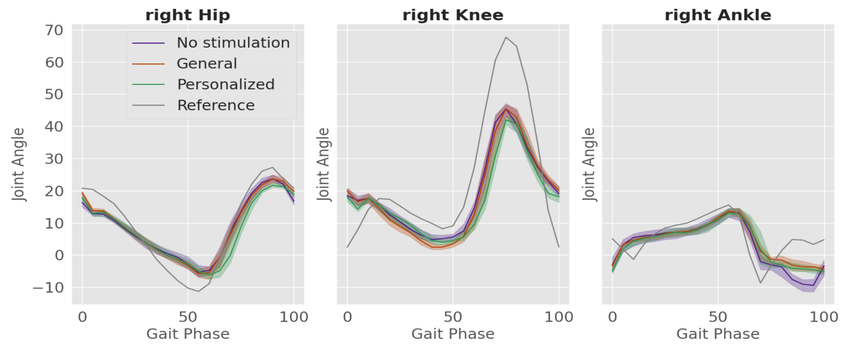


Figure: Joint angle trajectories for patient 3

⇨ Informative metrics for FES patterns assessment: walking speed, stride length, kinematic analyses, hip ROM and metrics of postural sway and asymmetry are informative for FES patterns assessment.

CONCLUSION

- FES improved walking speed, stride length and asymmetry in gait and evaluated metrics are useful for assessing FES patterns.
- Patient-dependent improvements reveal the need for a more comprehensive clinical gait rehabilitation framework.

REFERENCES

•***Andreopoulou et al. (2024).*** Is functional electrical stimulation effective in improving walking in adults with lower limb impairment due to an upper motor neuron lesion? An umbrella review. *Artificial Organs*
•***Kim et al. (2019)*** Using Inertial Sensors to Quantify Postural Sway and Gait Performance during the Tandem Walking Test, *Sensors*.
•***Rössler et al. (2024)***, Spatiotemporal gait characteristics across the adult lifespan: Reference values from a healthy population – Analysis of the COmPLETE cohort study, *Gait & Posture*

More infos

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