

Evaluating the Effects of Exoskeleton Operational Mode on Electromyography during Overground Walking in Cases of Spina Bifida and Cerebral Palsy

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Introduction

- Crouch gait is commonly observed in children with cerebral palsy (CP) and spina bifida (SB) and is characterized by excessive knee and/or hip flexion and ankle dorsiflexion.^{[1][2]}
- Current treatments including surgery, botulinum toxin injections, and physical therapy have varying effectiveness^[3].
- Robotic exoskeletons are emerging as a promising option for improving mobility and function via rehabilitation.
- Electromyography (EMG) provides a method to quantify muscle activation and therefore assess the potential of an exoskeleton as a rehabilitation tool.
- Muscle synergies are coordinated patterns of muscle activity used to produce functional movements.
- Therefore, the number of muscle synergies deployed during a movement can be used to quantify control complexity.

Objectives

- To assess the effects of three exoskeleton modes on muscle activity and complexity during overground walking.
- To examine changes in those effects across 9 total visits walking with the exoskeleton (Fig. 1).

Methods

- EMG was collected from 5 muscles bilaterally (rectus femoris, semitendinosus, vastus lateralis, medial gastrocnemius, and tibialis anterior) at 2000 Hz during overground walking in three exoskeleton modes (Fig. 2).

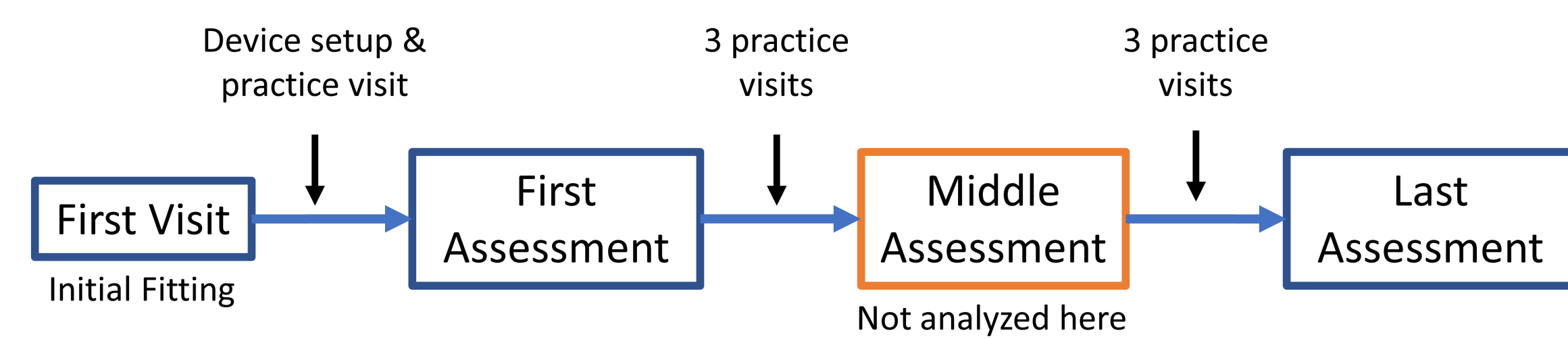


Fig. 1: Flow chart of the ten-visit study.

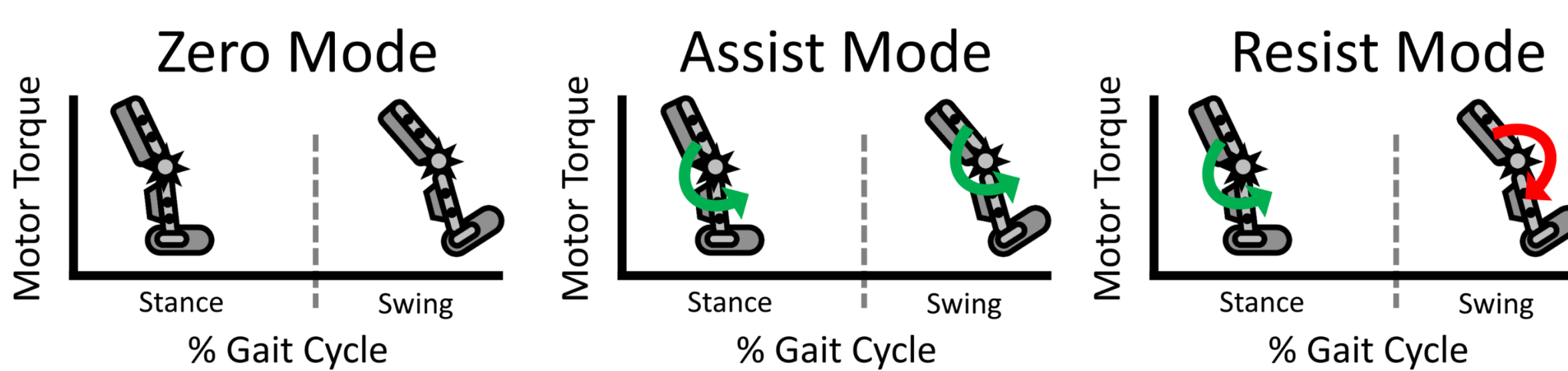


Fig. 2: The three exoskeleton modes examined in the study.

Participants

- 2 with CP (female, 13 and 25 years)
- 1 with SB (female, 9 years)
- All participants used crutches or walker

Outcome Measures

- EMG activation (area under the curve (AUC) for stance and swing
- Number of muscle synergies that account for 90% total EMG variance



Fig. 3: Participant walking with the exoskeleton.

Main Finding

Knee extension resistance during swing increased vastus lateralis activity whereas the effects of assistance during stance were more variable across all participants.

Muscle synergy analysis suggests that the extension assistance increased complexity of muscle coordination in the last assessment.

Results

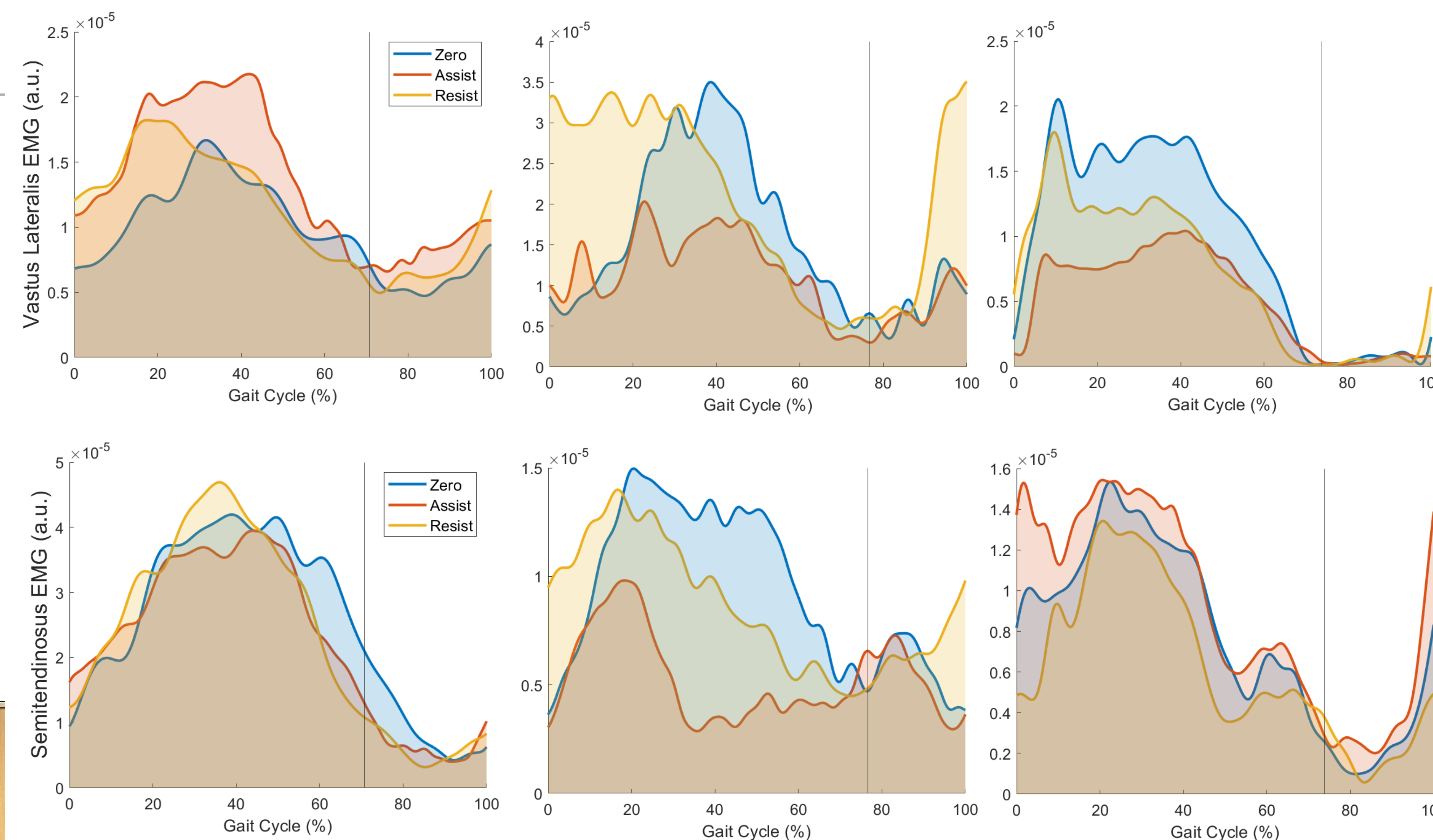


Fig. 4: Mean vastus lateralis (top row) and semitendinosus (bottom row) activity for EX202 (left), EX203 (middle), and EX205 (right) during overground walking with each exoskeleton mode.

Acknowledgements

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Results

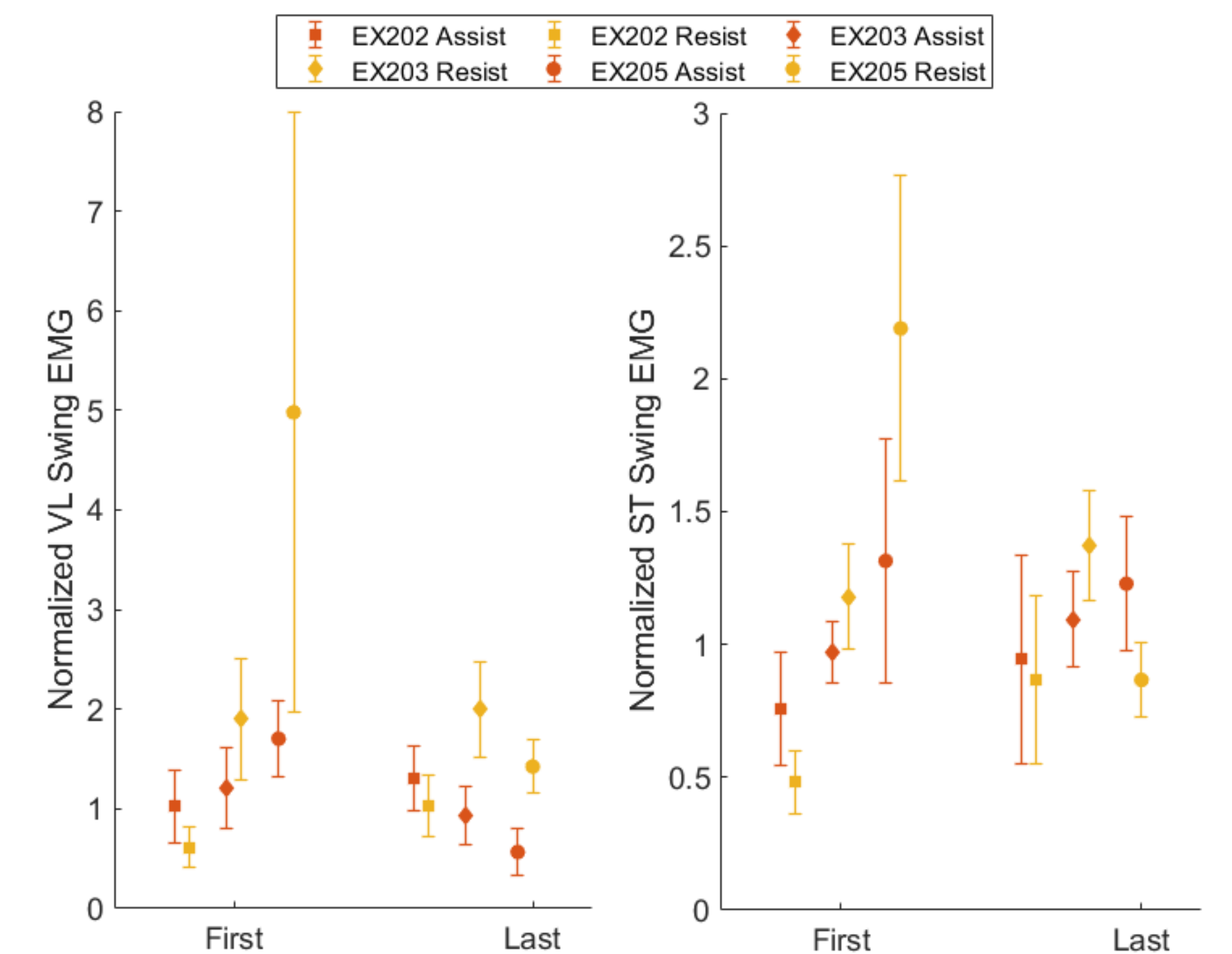


Fig 5: Mean total activity of vastus lateralis (left) and semitendinosus (right) normalized to the zero condition for each subject and visit.

Table 1. Number of muscle synergies by exoskeleton mode.

Subject	Visit	Mode		
		Zero	Assist	Resist
EX202	First	3.75 (.433)	4.00 (0.00)	3.40 (.490)
	Last	3.40 (.490)	4.20 (1.38)	3.53 (.500)
EX203	First	5.00 (0.00)	3.29 (.452)	3.59 (.691)
	Last	3.46 (.499)	4.46 (.499)	3.41 (.492)
EX205	First	3.00 (0.00)	3.44 (.497)	3.04 (.196)
	Last	3.00 (0.00)	3.67 (.471)	3.08 (.266)

Data are presented as mean (std dev)

Discussion

- EMG response to exoskeleton mode was individual specific.
- Reduced knee extensor EMG in mid-stance was associated with improved knee extension indicating this posture can reduce fatigue and improve mobility.
- Increased knee extensor EMG during late swing is a potential predictor for positive training outcomes from the resist mode.
- The participant with SB (EX203) appeared to show most benefit from resist mode, possibly because her crouch was primarily weakness based.
- In CP crouch can be due to motor control issues as indicated by elevated ST response to extension assistance in some cases.

References

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