OPTIMIZING MUSCULOTENDON PARAMETERS TO SIMULATE WALKING WITH ANKLE-FOOT ORTHOSES IN CHILDREN WITH CEREBRAL PALSY

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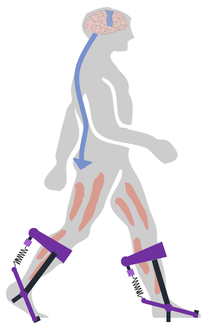
BACKGROUND

Cerebral Palsy (CP) derives from injury to the motor cortex and results in altered musculotendon properties, gait kinematics, and motor control.

Ankle-Foot Orthoses (AFOs) are commonly prescribed to improve gait kinematics for children with CP. However, current prescription methodologies are ineffective and may be better informed using subject-specific modeling paradigms[1].

Musculoskeletal models can capture subject-specific response to AFOs, but are often based on adult-average muscle-tendon unit (MTU) and motor control parameters which are generally invalid for people with CP[2].



DRIVING QUESTION

Can optimizing muscle and tendon parameters in a musculoskeletal model improve the accuracy of simulated muscle activation for children with cerebral palsy while walking with ankle-foot orthoses?

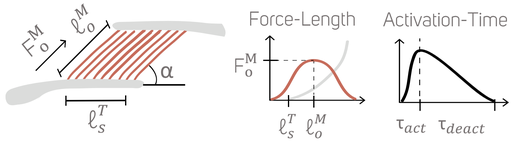
METHODS

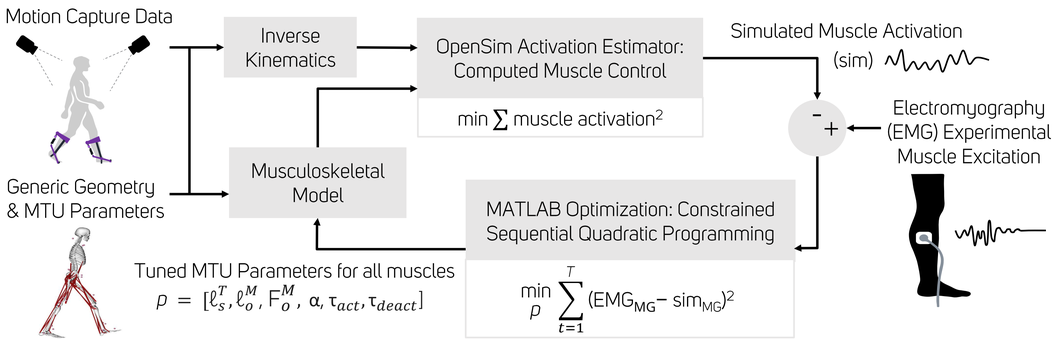
1 subject with diplegic CP and bi-lateral AFOs.

5 leg muscles: hamstrings (biceps femoris, BF), quadriceps (rectus femoris, RF, vastus intermedius, VI), calf (medial gastrocnemius, MG), shin (tibialis anterior, TA).

Optimization was focused on the **medial gastrocnemius (MG)** since it is heavily impacted by CP[3], influences both ankle and knee motion, and can be used to control orthoses[4].

6 MTU parameters: tendon slack length (ℓ_s^T), optimal fiber length (ℓ_o^M), pennation angle (α), maximum isometric force (F_o^M), activation and deactivation time constants (τ_{act}, τ_{deact}).

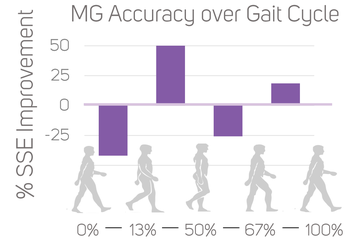


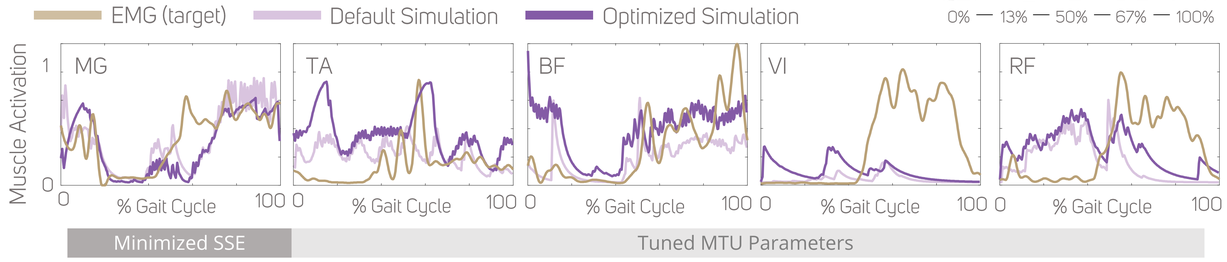


RESULTS

Generic MTU parameters estimate muscle activations poorly; optimized parameters locally improve estimates.

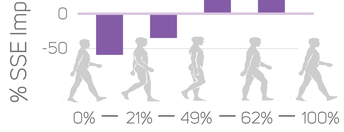
OpenSim assumes independent muscle control[5], while children with CP co-activate agonist-antagonist muscle pairs[6]. This may explain why some muscle activations could not be matched.

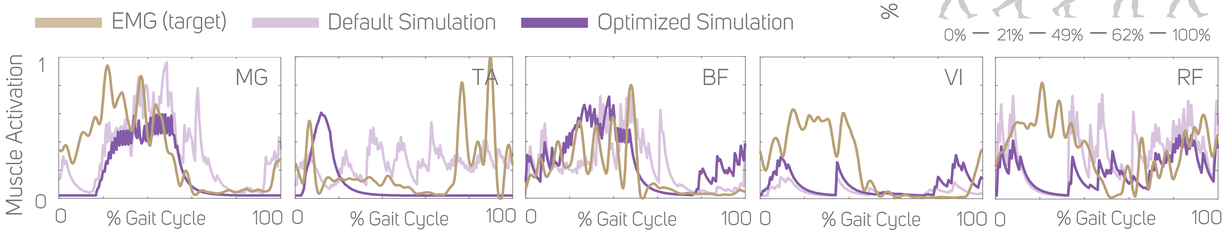




Optimal parameters span multiple AFO walking trials.

Optimal MTU parameters showed local improvements in prediction accuracy for a second gait cycle, supporting the generalizability of optimized MTU parameters.





DISCUSSION

Optimizing muscle and tendon parameters can improve subject-specific models of walking with AFOs.

1. Co-activation is not captured by optimal MTU parameters.
To match observed behavior, musculoskeletal models should constrain muscles to co-activate.

2. Accuracy is variable across the gait cycle.
Results may improve by optimizing over phases of the gait cycle or by prioritizing regions with high initial error.

3. Future testing should extend to multiple subjects and walking conditions.
AFO prescriptions could be streamlined if optimal MTU parameters from barefoot walking were shown to capture muscle activation during AFO use.

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REFERENCES

[1] Ries AJ, et al. Phys Med & Rehabil, 7, 2017.
[2] Meyer AJ, Patten C, and Fregly BJ. *PLoS ONE*, 12(7), 2017.
[3] Barber L, et al. Dev Med & Child Neurol, 53, 2011.
[4] Grazi L, et al. IEEE 37th Conf. EMBC, 2015.
[5] Delp SL, et al. IEEE 54(11), 2007.
[6] Steele KM, et al. Dev Med Child Neurol, 57(12) 2015.