Muscle Co-activation Patterns from Synergies Fail to Capture Motor Control Deficits in Physics-based Gait Simulations of Children with Cerebral Palsy

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Summary

We predicted the gait pattern for eight children with cerebral palsy, using synergy-based control constraints and personalised musculoskeletal models. Our results suggest that synergies alone may not fully capture motor control deficits.

Introduction

Selecting the best treatment for children with cerebral palsy (CP) is challenging given the heterogeneity of gait impairments [1]. Physics-based optimal control simulations [2] are a potentially powerful tool to understand complex relationships between altered neuromuscular properties and treatments, and their effects on the gait pattern. To this end, an important challenge is to accurately model patient-specific musculoskeletal impairments and non-selective muscle control to capture gait deviations of children with CP. Muscle synergies can be used to describe the ability to selectively control muscles. Children with CP walk with fewer synergies than typically developing individuals, and their synergies structure does not significantly change after treatment [3]. Here, we evaluated whether using synergies derived from muscle electromyography (EMG) during walking to constrain muscle excitations in physics-based simulations improves simulation accuracy.

Methods

Gait analysis and clinical exam were performed in eight children with CP as part of their usual clinical care. Muscle synergies were extracted from the EMG signals of eight muscles using non-negative matrix factorisation. We selected the number of synergies needed to explain at least 90% of the variance accounted for (VAF) of the measured EMG. Starting from a model per each child (*GEOMUS*) that included personalised skeletal geometries (based on MRI images), and muscle weakness and contractures (based on clinical exam) [4], motor control was personalised by imposing the number of synergies (*Syn N*) and the muscle co-activation patterns (*Syn W*) derived from the synergy analysis. For each model, we predicted the gait pattern by computing muscle excitations minimising a movement-related cost while imposing the average walking speed and periodicity [2]. We compared the predicted kinematics and muscle activity with those measured experimentally.

Results and Discussion

We found that lower body joint angles were less accurately predicted with *GEOMUS* for subjects with higher motor control impairment (Fig. 1, left). This suggests that modelling motor control, in addition to personalised bone geometries, muscle weakness and contractures, is more critical when the motor impairment is higher. However, adding synergies to model motor control impairments did not improve the agreement between measured and simulated joint kinematics (Fig. 1, right) and muscle activity. This may indicate that imposing a reduced number of synergies or muscle co-activation patterns from synergies does not fully capture motor control impairments. A critical aspect to be considered in future work is how to distinguish real neural impairment (non-selective muscle control) from task specific coordination, which may be both included in the synergy co-activation patterns.

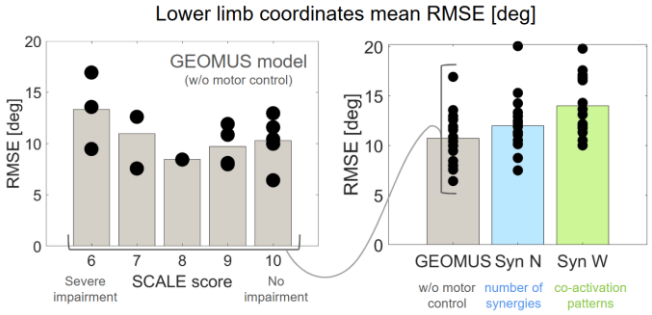

Figure 1: **Left**: Mean RMSE between predicted and experimental lower body joint angles per subject and side (right, left) with respect to the selectivity clinical score. **Right**: Mean RMSE between predicted and experimental lower body joint angles for each model-leg. **Both**: Dots correspond to each subject-leg (16 in total), bars correspond to the mean of all subjects-legs with the same clinical score.

Conclusions

Our results suggest that modelling motor control is more critical when the motor impairment is higher, and that imposing muscle co-activation patterns from synergies does not fully capture motor control impairments. In the future, we will assess co-activation patterns across movements including isolated joint movements, as well as other functional activities, for a wider group of subjects.

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References

[1] Ries, A. J. et al. (2015) *PM&R* 7, 922–929.
[2] D'Hondt, L. et al. (2024) *Proc. BioRob* (1208-1213).
[3] Pitto L, et al. (2020) *PLoS ONE* 15(2): e0228851.
[4] Van Den Bosch, B., et al. (2024) Gait & Posture, 113(S1), 229-230.