EMG-ASSITED METHOD AND UNCONTROLLED MANIFOLD THEORY TO EXPLORE SUBOPTIMAL CONTROL IN CHILDREN

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Introduction

Commonly, biomechanical simulations employing musculoskeletal models assume that to perform simple locomotor tasks the central nervous system selects a neural strategy that minimises the metabolic cost, i.e. optimal control. This is likely not valid for pathological populations with neuromuscular disorders (e.g., cerebral palsy, CP) who tend to adopt suboptimal control strategies. Alternative methods, such as the EMG-assisted [1] and probabilistic [2] approaches, have been developed and tested to the purpose.

In this work we explored different ways to model the muscle activation patterns in children with CP and typically developing (TD) age-matched controls. Specifically, we compared the knee joint contact forces estimated through standard static optimisation, an EMG-assisted method and a probabilistic approach.

The aim was to evaluate differences among methods and to understand whether the EMG-assisted solution could be explained as a stochastic variation from optimal solution for healthy and pathological subjects.

Methods

Subject-specific musculoskeletal models were developed using nmsBuilder [3] for three children with CP (GMFCS I-II, age: 8.35±2.01 years, height: 1.25±0.12 m, mass: 23.30±5.33 kg) and three age-matched TD children (age: 7.98±1.75 years, height: 1.23±0.10 m, mass: 24.47±6.02 kg). Bone geometries, muscle paths and muscle maximal isometric forces were personalised using magnetic resonance images. Biomechanical simulations of ten walking trials were performed in OpenSim (v4.1) [4] using static optimisation and EMG-assisted approaches (CEINMS [1]). A probabilistic approach was used to estimate 2e5 plausible solutions combining Bayesian statistics and Markov Chain Monte Carlo algorithm (Metabolica [5]) to explore the solution space within a 5% and 10% variation from the optimal solution (i.e., static optimisation).

Results

For the TD children, the static optimisation and EMG-assisted approaches produced similar knee contact force profiles. Only few discrepancies were observed, of relatively small magnitude (less than 1 BW). In all three cases, the EMG-assisted solutions fell tendentially within a 5% manifold (variation from the optimal solution) generated by the stochastic approach.

For the CP children, a common trend was not observed. The discrepancies between EMG-assisted and static optimisation estimates were generally larger than in the TD cohort. In one case, in particular, the EMG-assisted solution fell outside of the 5% manifold (but within 10% variation from the optimal solution)(Figure 1).

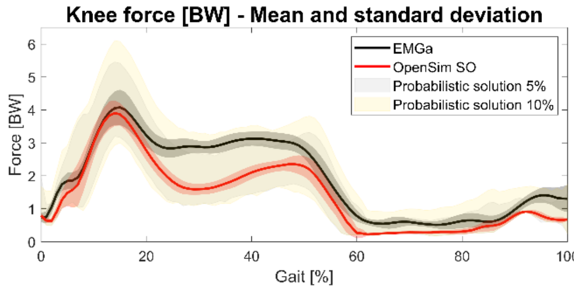

Figure 1: Knee contact force predictions for a CP child, expressed in bodyweights (BW). Comparison of EMG-assisted (black), static optimisation (red) and probabilistic solutions (grey shaded area for 5% variation and yellow shaded area for 10% variation).

Discussion

The purpose of this study was to compare three different methods to model suboptimal muscle activation patterns. These preliminary findings suggest that for healthy individuals the EMG-assisted and static optimisation methods produce similar results, which are contained in a narrow manifold. However, the same does not hold true for children with CP, for whom EMG-assisted predictions may largely deviate from an optimal solution. Further work is warranted to support these results.

References

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