MODELING SUBOPTIMAL MUSCLE CONTROL IN PATIENTS WITH PARKINSON'S DISEASE

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Summary

A novel stochastic approach was employed to estimate a band of plausible suboptimal muscle and joint contact forces in four subjects with and without Parkinson's disease during walking. Combined with methods to reduce data complexity and enhance interpretation, this approach has the potential to provide valuable information to support and guide the clinical management of patients with neuromuscular disorders.

Introduction

Neuromuscular disorders such as Parkinson's disease are known to affect a person's ability to perform their activities of daily living (including walking). Understanding the forces that a joint experiences during motion and identifying alternative motor control strategies that minimize joint loading while preserving the kinematics may be important. A novel stochastic approach (Myobolica) promises to enable this. However, to date, the tool has been solely tested on one subject with a knee implant.

Methods

In this study, we used motion capture and ground reaction force data from four female subjects (healthy young adult – HYA, healthy older adult – HOA, patient with mild PD - PD1, patient with severe PD – PD3)(Table 1) who walked at self-selected walking speed on level ground, exploiting data from a former study [1] and a publicly available dataset [2].

Table 1 Subjects demographics. H&Y = Hoehn & Yahr score.

Subject	Sex	Age (y)	BMI (kg/m^2)	Condition
HYA	F	27	21.09	Healthy
HOA	F	66	21.45	Healthy
PD1	F	58	21.64	PD, H&Y1
PD3	F	61	24.08	PD, H&Y3

Upon data processing, the generic Full Body Model [3] was linearly scaled to the subjects' size and employed to perform biomechanical simulations of gait in OpenSim, where the traditional inverse approach was followed to estimate (1) joint kinematics and kinetics, (2) muscle moment arms, activations and forces, and (3) joint contact forces. The OpenSim estimates were then provided to Myobolica (stochastic approach)[4], which we used to identify 10k physiologically plausible solutions per participant. Each simulation in Myobolica took up to 1 h on a standard workstation. The constitutive parameters of the tool, which determine its behavior, were set to 0.12 (σ, uncertainty on the measures) and 0.03 (γ, muscle force smoothness). The resulting joint contact forces were interpolated to 101 points, ordered in percentiles, and normalized to the subject's bodyweight to allow for comparisons. To assess the results, we computed the coefficient of determination (R^2) and the root mean squared error (RMSE) between the optimal solution and the median solution from Myobolica.

Results and Discussion

In general, the optimal solution from OpenSim was associated with the lowest knee joint loads, contouring the band of solutions identified by Myobolica (Figure 1). For the two healthy subjects (HYA, HOA), the median solution from Myobolica was ~3 BW larger than the SO estimate. On the other hand, PD1 and PD3 exhibited respectively the most and least suboptimal median solutions ($RMSE_{PD1}$ = 3.63 BW vs $RMSE_{PD3}$ = 2.14 BW), suggesting that disease severity can limit one's ability to recruit muscles adopting different strategies. Of note, PD3 walked very slowly, taking short (in length) but long (in time) steps.

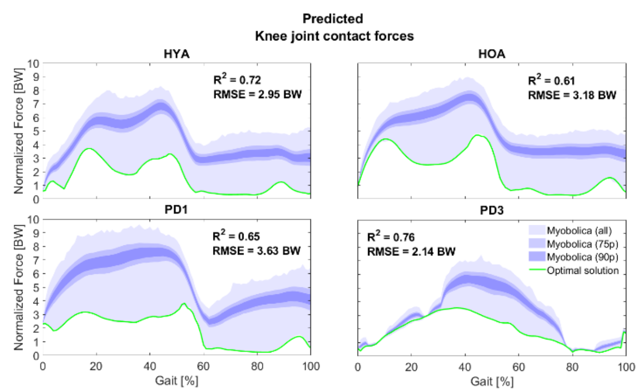

Figure 1: Knee joint contact forces predicted via static optimization (SO, green) and stochastic approaches (Myobolica, blue).

Conclusions

Myobolica was used to estimate joint loads resulting from suboptimal control strategies in subjects with neuromuscular disorders and healthy adults, yielding promising results.

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