Framework for evaluating rehabilitation outcomes in Parkinson's disease with an exoskeleton: an EMG-informed musculoskeletal modeling approach

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Summary

Parkinson's Disease (PD) is a neurodegenerative disorder characterized by motor and non-motor symptoms. Treatment typically involves rehabilitation to enhance motor function, neuroplasticity, and quality of life. Exoskeletons are a novel approach aimed at improving gait and postural stability, addressing muscle weakness, a key feature of PD.

This study evaluates the effectiveness of exoskeleton-assisted rehabilitation in PD by assessing muscle forces during gait using an EMG-informed neuromusculoskeletal modeling (NMSM) framework. Two PD groups underwent gait analysis before and after rehabilitation with exoskeletons or standard Functional Kinetic Therapy (FKT).

Results showed that the exoskeleton group exhibited higher muscle forces, resembling healthy individuals, and reduced variability compared to the FKT group. These findings suggest that exoskeletons enhance muscle function in PD during gait.

Introduction

In recent decades, physical training has emerged as an effective complementary therapy for managing motor symptoms in PD[1]. Various methods have been introduced, ranging from traditional FKT to advanced overground robotic gait training ORGT, both aimed at promoting neuroplasticity and restoring functional gait[2].

Methods

24 individuals with Parkinson's disease (PD) were enrolled in the study (ClinicalTrials.gov NCT04778852) and divided into two groups for a 4-week therapy. The first group (n=12, Age: 69.17±8.19 years, BMI: 25.97±3.31 kg/m²) underwent ORGT, while the second group (n=12, Age: 72.00±6.45 years, BMI: 23.96±2.37 kg/m²) received standard FKT. Additionally, 13 healthy controls (Age: 57.83±11.89 years, BMI: 25.73±3.47 kg/m²) were included.

Gait data were collected at the Fresco Parkinson Institute's Villa Margherita (Vicenza, Italy) before (T0) and after (T1) therapy using an 8-camera optoelectronic system (120 Hz, Vicon), two force plates (960 Hz, AMTI), and an 8-channel EMG system (2000 Hz, Cometa). EMG signals from four muscles (Rectus Femoris, Biceps Femoris, Tibialis Anterior, Gastrocnemius Lateralis) were recorded bilaterally.

The IORGait protocol was used [3]. A muscle-optimized [4]scaled model in OpenSim computed joint torques and muscle-tendon moment arms. Muscle forces were estimated via CEINMS [5], using EMG-driven simulations to optimize joint torques. One-dimensional statistical parametric mapping [6] assessed differences between groups.

Results and Discussion

Figure 1 shows group differences at T1: the ORGT group exhibited muscle force profiles similar to those of healthy subjects, particularly in the muscles of the posterior kinetic chain, during the early phases of stance when load acceptance occurs.

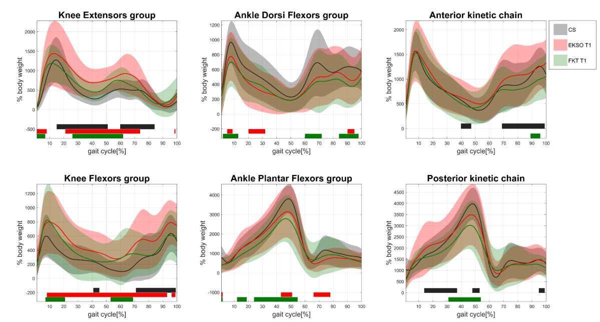

Figure 1:Functional groups' estimated forces. EKSO T1, FKT T1: mean ± standard deviation: *statistical significance ($p < 0.05$)

Conclusions

These findings suggest that ORGT training leads to muscle force profiles resembling those of healthy individuals, particularly in the posterior kinetic chain during load acceptance phases. Future studies could investigate whether the improvements observed in the ORGT group are associated with enhanced upright stability and correlate with clinical scales

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