How Can Electromyography Inform Clinical Decision-Making in Post-Surgical Gait Outcomes in Cerebral Palsy?

Mehrdad Davoudi[1], Firooz Salami[1], Robert Reisig[1], Dimitrios A. Patikas[2], Nicholas A. Beckmann[1], Katharina S. Gather[1], Sebastian I. Wolf [1]

[1] Clinic for Orthopaedics, Heidelberg University Hospital, Heidelberg, Germany

[2] Laboratory of Neuromechanics, School of Physical Education and Sports Science at Serres, Aristotle University of Thessaloniki, Greece

Email: Mehrdad.Davoudi@med.uni-heidelberg.de

Summary

This study examines changes in electromyography (EMG) patterns after multilevel surgery in cerebral palsy (CP) patients and the connection between EMG-based motor control indices and surgical outcomes. Retrospective EMG and gait data from 167 CP patients, who underwent at least one soft tissue surgery on shank or foot muscles, were analyzed pre- and post-surgery. Norm-distance (ND) for gait and EMG was analyzed using Repeated Measures ANOVA. Patients were grouped into different gait responders based on changes in the Gait Deviation Index (GDI) using K-means-PSO. Post-surgery, significant improvements were seen in gait parameters ($p<0.05$), with ND reductions in rectus femoris ($p<0.001$) and soleus ($p=0.006$). Although the Dynamic Motor Control Index (DMC) remained unchanged ($p=0.88$), higher pre-operative DMC values correlated with greater gait improvements, especially in poor responders ($p<0.05$). DMC may predict outcomes, particularly in patients with poor pre-operative gait. Further research is needed to assess the impact of different surgical strategies.

Introduction

Cerebral palsy (CP) is a prevalent childhood disability that significantly affects gait and muscle activation. Electromyography (EMG) offers valuable insights into neuromuscular function [1,2], yet its role in CP treatment planning remains underexplored. This study investigates the impact of Single Event Multilevel Surgery (SEMLS) on EMG and gait parameters in patients with CP, focusing on soft tissue surgery of the shank and foot. Additionally, it explores the potential of EMG and motor control indices as predictors for surgical outcomes, aiming to enhance clinical decision-making and guide personalized treatment strategies.

Methods

This study retrospectively analyzed data from 167 patients with CP who underwent at least one soft tissue surgery on their shank and foot muscles, in addition to 117 typically developed individuals used as a reference. Participants' gait was assessed before and after surgery using 3D motion analysis and EMG recording, capturing muscle activation patterns from key lower-extremity muscles. We employed Repeated Measures ANOVA to evaluate norm-distance (ND) changes in kinematics, kinetics, and EMG patterns, as well as specific indices such as the Kerpape-Rennes EMG-based Gait Index (EDI), EMG Profile Score (EPS), and Walking Dynamic Motor Control Index (DMC) [2]. The Gait Deviation Index (GDI) scores were used to categorize the patients into different response groups (good, mild, poor), with subsequent comparisons between the groups utilizing the Mann-Whitney test for nonparametric analysis. These analyses enabled us to investigate the surgery's effect on gait patterns and muscle activation, drawing correlations with post-surgical recovery levels. The K-means-PSO clustering algorithm was applied to classify participants based on their GDI scores, to remove the effect of the pre-treatment gait influence on outcomes.

Results and Discussion

The results of this study underscore the significant improvement in kinematic and kinetic parameters post-surgery, with all measured metrics demonstrating statistically significant improvements ($p<0.05$). While EMG activity showed marked reductions in ND for the rectus femoris ($p<0.001$) and soleus ($p=0.006$), the DMC, a motor control index, remained unchanged ($p=0.88$). Importantly, the pre-operative DMC score was found to be a significant predictor of surgical success, particularly for those with poor pre-treatment gait. Patients with low pre-operative gait quality (GDI≈40/100) and motor control (DMC≈70/100) could benefit from motor control interventions before surgery, potentially improving outcomes. In contrast, those with better gait (GDI≈70/100) and higher DMC scores (≈80/100) are more likely to experience significant surgical benefits, informing tailored treatment plans and enhancing clinical decision-making.

Conclusions

A higher pre-operative DMC score was associated with better post-surgical outcomes, suggesting that motor control interventions may be especially beneficial for patients with lower DMC scores before surgery. These results underscore the importance of integrating DMC and EMG indices in pre-surgical evaluations, providing clinicians with valuable tools to predict surgical outcomes and tailor treatment plans accordingly. This approach can enhance clinical decision-making and improve recovery for individuals with CP.

References

[1] Davoudi M et al. (2024). *PloS One*, **19(8)**: e0298945.

[2] Davoudi M et al. (2025). *PloS One*, **20(1)**: e0309582.

[3] Schwartz MH et al. (2016). *Dev Med Child Neurol*, **58**: 1139-1145.