Does including EMG data in the estimation of muscle forces alter the evaluation of the effect of botulinum toxin injections?

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Introduction

Children with cerebral palsy (CP) present altered electromyography (EMG) activity [1]. Botulinum Toxin Injections (BTI) are used to reduce the spasticity of specific muscles. Muscle forces can be calculated with musculoskeletal models by either a static optimization (SO), which does not take EMG activity into account, or an EMG-constrained optimization. Considering children with CP have distinct EMG deviations, an EMG-constrained approach seems more appropriate.

Research Question

Does including EMG data in the estimation of muscle forces alter the evaluation of the effect of BTI on muscle force distribution?

Methods

Fourteen children with spastic diplegic CP (7.25 ± 1.15 years) and ten typically developing (TD) children (8.00 ± 1.60 years) were included. All CP children received multilevel BTI in the hamstrings and psoas and 12 children also in the gastrocnemius. All children joined a gait analysis session, the CP children prior and six weeks after BTI. Three representative strides of the right and left limb were selected. Marker trajectories (Vicon, Oxford Metrics, UK) and ground reaction forces (AMTI, Watertown, MA) were captured. Surface EMG activity was collected for the rectus femoris, biceps femoris, vastus lateralis, semitendinosus, tibialis anterior, gastrocnemius, soleus, and gluteus medius (Zerowire, Cometa, Italy). A musculoskeletal model (Gait2392) was scaled to the dimensions of each subject (OpenSim 3.3). A Kalman smoother algorithm calculated joint kinematics. Individual muscle forces were calculated using 1) standard SO and 2) EMG-constrained SO (EMGcon). Average muscle forces during initial double support (IDS), single stance (SS), terminal double support (TDS) and swing phases were calculated and normalized to body mass. Results are presented for the medial hamstrings and gastrocnemius, as these were the main muscle groups for BTI. Paired t-tests were used to 1) evaluate if there were differences in muscle forces between EMGcon and SO (method effect) in each participant group and 2) to evaluate if the change in muscle forces from the pre to post BTI data collection session differed when using an EMGcon or SO approach (treatment effect).

Results

Figure 1. Average medial hamstrings and gastrocnemius muscle forces for the difference phases of the gait cycle for TD (top), BTI_{pre} and BTI_{post} (bottom) children when using EMG constraint (EMGcon) and static optimization (SO). Statistical differences between muscle forces calculated using EMGcon and SO are indicated using the colored asterisks (blue, red and green for TD, BTI_{pre} and BTI_{post} respectively). Black asterisks in the bottom graphs indicate differences between BTI_{pre} and BTI_{post} using either EMGcon or SO.

Muscle forces were significantly increased ($p < 0.05$) when using EMGcon compared to SO for both TD and CP children for all phases of the gait cycle (figure 1), except for the gastrocnemius in SS. Significantly decreased muscle forces were found in IDS post BTI in the medial hamstrings and gastrocnemius when using both EMGcon and SO. For the gastrocnemius, a significantly higher muscle force in TDS was only observed when using SO.

Discussion

Compared to SO, EMGcon led to higher muscle forces in TD and CP children, as increased co-contraction were included. The use of SO, without accounting for increased co-activation, affects the observed muscle force distribution and therefore may alter the observed treatment effect at a muscle level.

References

[1] Unnithan+, Electromyogr. Clin. Neurophysiol. (1996).