Title

Impaired Neural Modulation of Muscle Activation During Walking in Hemiplegic Cerebral Palsy

Authors/Affiliations

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Background

Impaired walking performance in cerebral palsy (CP) is associated with muscle weakness, attributed to both intramuscular structural alterations and impaired neural activation, including a predominance of smaller motor units with limited capacity to increase firing rate [1,2]. High-density surface electromyography enables in-vivo assessment of individual motor unit (MU) behaviour during walking.

Objectives

To characterize MU activation during walking in individuals with CP hemiplegia compared with typically developing (TD) peers.

Methods

Nine individuals with CP (GMFCS I–II; mean age 12.1±3.5 years) and six TD individuals (mean age 11.8±2.7 years) walked on a treadmill at self-selected speed (CP: 0.86±0.23 m/s; TD: 1.18±0.12 m/s). Medial gastrocnemius activity was recorded bilaterally using a Delsys Galileo sensor during one minute of walking. Signals were decomposed into individual motor units [3], and analyses were restricted to units with decomposition accuracy ≥90%. Peak motor unit action potential (MUAP) amplitude was used as a proxy for MU size, reflecting force capacity, while mean MU firing rate served as an index of neural drive. To examine neural modulation independent of MU size, MUAP amplitudes were normalized within each leg. Group differences were assessed using Kruskal–Wallis testing with post-hoc comparisons.

Results

Group differences were evaluated across TD, CP hemi and non-hemi limbs. While median MUAP amplitudes were similar between CP hemi and non-hemi limbs, the 90th percentile MUAP amplitude differed significantly between groups (Kruskal–Wallis H=11.36, p=0.003). The upper end of the MUAP distribution was lower in hemi limbs (88.2 μV, IQR 67.1–96.5) and non-hemi limbs (96.7 μV, IQR 65.8–228.2) than in TD limbs (224.9 μV, IQR 152.7–331.1). Post-hoc analysis showed TD differed from hemi limbs (Holm-adjusted p = 0.005) with a very large effect size (rank-

biserial |r|=0.83), indicating reduced representation of higher-amplitude motor units in hemi limbs. Across all groups, mean MU firing rate scaled inversely with MUAP amplitude. TD and CP non-hemi limbs showed clear differentiation of firing rate across motor unit sizes, whereas CP hemi limbs exhibited a flatter rate–amplitude relationship with reduced separation of firing rates across the available motor unit pool. These deficits were not strongly related to GMFCS level, walking speed, or ankle dorsiflexion range.

Conclusion

During walking, hemiplegic limbs in CP exhibit both reduced force-generating capacity and impaired neural drive. These findings suggest that weakness in CP is not solely structural but also reflects impaired rate coding during gait, potentially contributing to gait inefficiency and fatigue.

References

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