Muscle Architecture Differences in Medial Gastrocnemius of Adolescents With Both Spastic and Non-Spastic Cerebral Palsy Compared to Typically Developing

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Summary: This study used diffusion tensor imaging (DTI) to assess medial gastrocnemius architecture in adolescents with cerebral palsy (CP) typically developing (TD) controls. CP participants had shorter muscles, higher pennation angles, and increased apparent diffusion coefficient (ADC) values, consistent with spasticity. These differences appeared in both spastic and non-spastic participants, suggesting muscle changes may occur without a spasticity diagnosis.

Introduction: Understanding muscle architecture in CP is crucial for tailoring rehabilitation and improving quality of life. Differences between CP and TD adolescents may reflect altered growth patterns or mechanics during rapid development [1]. Assessing muscle architecture is challenging, but in vivo imaging methods like DTI offer powerful insights into both architecture and muscle quality. With this in mind, we evaluated the medial gastrocnemius muscles in two adolescent cohorts: one with CP and one TD control group.

Methods: Imaging data from five adolescents with CP and five TD controls from a previous study were used [2]. All participants provided informed assent, and parents/guardians gave consent. The University of Auckland Human Participant Ethics Committee approved the study. Two MRI sequences were acquired: a sagittal T1VIBE sequence for anatomical muscle data and an echo-planar DTI sequence of the same region. The medial gastrocnemius was segmented in T1VIBE datasets to create masks for DTI analysis. Tractography was performed in DSI Studio, and muscle architecture was calculated using custom Python code, following Bolsterlee's methods [3].

Results and Discussion: Pennation angles were significantly larger in the CP cohort at both the proximal (25.0 ± 3.5˚ CP vs. 21.0 ± 2.6˚ TD, p = 0.036) and distal (28.9 ± 3.5˚ CP vs. 24.2 ± 2.3˚ TD, p = 0.008) aponeurosis (Fig. 1). Normalized muscle length was shorter in CP than TD (0.105 ± 0.013 vs. 0.125 ± 0.012, p = 0.038), while normalized fascicle lengths did not differ (0.0234 ± 0.0079 CP vs. 0.0237 ± 0.0079 TD, p = 0.922). Normalized muscle volume and physiological cross sectional area showed no significant differences. For DTI scalars, the ADC was higher in CP than TD (10^{-3}·(0.252 ± 0.025 mm²/s) vs. 10^{-3}·(0.178 ± 0.046 mm²/s), p = 0.019), while fractional anisotropy (FA) was similar (p = 0.802). Prior studies reported reduced pennation angles in the medial gastrocnemius of adolescents with CP. While our findings contrast this, they align with spasticity, where fascicles appear more contracted and ADC values are elevated. This pattern appeared in both spastic and non-spastic participants.

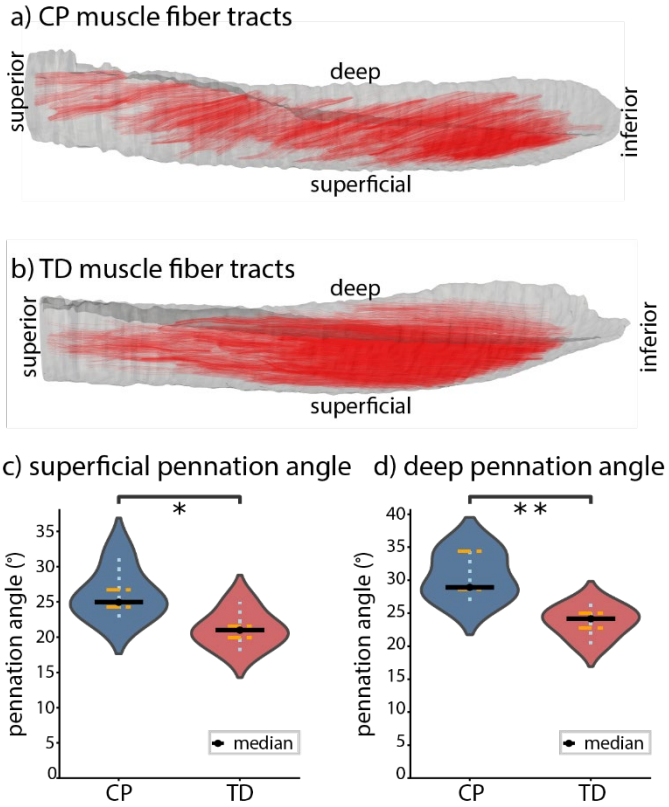

Figure 1: Muscle fiber differences between CP and TD in the medial gastrocnemius. Muscle fiber tracts from CP (a) and TD (b) show significantly different orientations with larger pennation angles for CP at both the superficial (c) and deep (d) aponeurosis.

Conclusions: Muscles were shorter in CP than TD, but fascicle lengths did not differ. CP participants also had higher pennation angles and increased ADC values, consistent with local spasticity. These effects appeared in both spastic and non-spastic participants, suggesting muscle changes may occur even without a spasticity diagnosis. Future work will expand the cohort to 10 participants and assess the tibialis anterior for comparison.

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References

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