Morphological and mechanical properties of spastic muscle in children and young adults with spastic cerebral palsy

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Abstract

Individuals with spastic cerebral palsy (CP) commonly experience muscle weakness, reduced range of motion, and increased stiffness of affected joints, which together contribute to reduced functional capacity. There is increasing awareness that muscular, in addition to neural factors, contribute to these deficits. The purposes of this thesis were to (1) develop and validate new ultrasound-based methods for assessing morphological properties of the human medial gastrocnemius (MG) muscle in vivo, and (2) to investigate the morphological and passive and active mechanical properties of the MG muscle in children and young adults with spastic CP.

Validation of new methods for assessing muscle morphological properties in vivo. A freehand three-dimensional ultrasound (3DUS) approach for assessing MG muscle volume and length was developed and validated against equivalent measurements made using magnetic resonance imaging (MRI). Compared to MRI, the freehand 3DUS approach overestimated muscle volume by 1.1% and underestimated muscle belly length by 1.3%. The 3DUS approach was also found to be highly reliable. A clinical method for measurement of MG muscle and tendon length was also developed and shown to have high accuracy and reliability compared to freehand 3DUS (Appendix C).

MG muscle physiological cross-sectional area (PCSA) in spastic CP. Compared to typically developed age-matched peers, PCSA of the MG muscle was reduced by 22% in young children aged 2-5 years, and by 37% in young adults aged 15-21 years. Reductions in MG muscle PCSA in the CP groups were primarily explained by a lack of volumetric muscle growth, and contribute to the muscle weakness observed in spastic CP.

Passive and active MG mechanical properties in young adults with CP assessed using dynamometry. Passive ankle stiffness was 51% higher and passive MG fascicle strain was 47% lower in the spastic group CP compared to typically developed controls. These findings suggest
that the increased resistance to passive ankle dorsiflexion in spastic CP is related to the inability of MG muscle fascicles to elongate with increased passive force. Compared to the typically developed group, the spastic CP group also produced 56% less active ankle plantarflexion torque across the available range of ankle joint motion, and had greater levels of antagonistic co-contraction and a longer Achilles tendon slack length. The increased Achilles tendon slack length may facilitate a greater storage and recovery of elastic energy and partially compensate for decreased force and work production by the muscles of the triceps surae during activities such as locomotion.

Overall findings from this thesis indicate that the morphological and mechanical properties of the MG muscle and Achilles tendon are altered in individuals with spastic CP, and together contribute to ankle plantarflexor muscle weakness, restricted ankle dorsiflexion range and increased ankle stiffness observed in CP. Treatments for improving function in spastic CP should be directed towards the muscular as well as neural system.
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Peer reviewed publications


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