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Passive muscle mechanical properties of the medial gastrocnemius in young adults with spastic cerebral palsy

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ABSTRACT

Individuals with spastic cerebral palsy (SCP) exhibit restricted joint range of motion and increased joint stiffness due to structural alterations of their muscles. Little is known about which muscle–tendon structures are responsible for these alterations. The aim of this study was to compare the passive mechanics of the ankle joint and medial gastrocnemius (MG) muscle in young adults with SCP and typically developed (TD) individuals. Nine ambulant SCP (17 ± 2 years) and ten TD individuals (18 ± 2 years) participated in the study. Physiological cross sectional area was estimated using freehand 3D ultrasound and found to be 37% lower in the SCP group. An isokinetic dynamometer rotated the ankle through its range while joint torque and ultrasound images of the MG muscle fascicles were simultaneously measured. Mean ankle stiffness was found to be 51% higher and mean MG fascicle strain 47% lower in the SCP group. Increased resistance to passive ankle dorsiflexion in SCP appears to be related to the inability of MG muscle fascicles to elongate with increased force.

1. Introduction

Spastic cerebral palsy (SCP) is a group of non-progressive motor impairment syndromes that occur secondary to lesions of the brain in the early stages of development (Bax et al., 2005). Spasticity is the key feature of SCP, and is neural in origin. However it is clear that spastic muscle also undergoes significant morphological and structural alterations in SCP, which contribute to muscle weakness, restricted joint range of motion and increased passive joint stiffness (Gracies, 2005) and corresponding reductions in function (Eek and Beckung, 2008). The key to further understand the mechanisms responsible for these joint level alterations is to examine architectural and mechanical properties of joint structures such as muscles and tendons (Lieber and Friden, 2001). Perhaps the most consistent finding from muscle level studies in SCP to date is that muscles in SCP are smaller compared to typically developing peers when expressed in terms of volume, cross-sectional area or muscle thickness (Barrett and Lichtwark, 2010). This finding, together with reports of collagen accumulation (Booth et al., 2001) and altered neural activation in SCP (Poon and Hui-Chan, 2009), would be expected to contribute to the reported muscle weakness in SCP (Wiley and Damiano, 1998). However it remains less clear what musculo-articular structures are responsible for restricted range of motion and increased stiffness at the joint level in SCP; commonly referred to as contracture. Increased non-neurally mediated joint stiffness in subjects with upper motor neuron lesions has been attributed to shorter muscles (Zhao et al., 2009) and muscles with shorter fascicles (Gao et al., 2009). However conflicting findings have been reported in SCP, because some studies report reductions in resting fascicle length (Mohagheghi et al., 2008; Moreau et al., 2009), while others report no differences (Malaiya et al., 2007; Shortland et al., 2002). It has also been suggested that reductions in muscle belly length reported in the absence of reductions in fascicle length in SCP could at least be partially explained by muscle fibre atrophy (Malaiya et al., 2007). Furthermore, although there is evidence for longer and more compliant tendons post-stroke (Zhao et al., 2009), no studies of tendon mechanical properties have been conducted in SCP.

Studies of whole muscle level architectural properties in SCP as mentioned above have primarily been confined to measurements of resting muscle belly and fascicle length/angle. These measurements are typically made at the resting joint angle, where muscle tension is assumed to be negligible, and so do not reveal information about muscle stiffness. The stiffness of individual muscle cells has, however, been reported to be substantially increased in spastic wrist muscle (Friden and Lieber, 2003), which depending on the number of muscle cells in series and their corresponding lengths, could explain joint level mechanical properties in SCP. In the only study to date investigating passive

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