**In vivo Evaluations of Fiber Tension and Sarcomere Imaging**

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**INTRODUCTION:**

Spasticity and contracture commonly occur in neurological disorders. Biomechanical changes of spastic muscle fibers are still not clear and mainly sarcomere length was investigated in spastic fibers in vivo. On the one hand, it was reported that single fibers from spastic muscle of children with cerebral palsy had shorter in vitro length of about 1.84 μm. On the other hand, in vivo sarcomere length of spastic muscles was found significantly longer, averaging 3.48 μm². Furthermore, it is not clear whether spastic fibers are under higher tension and stiffer under in vivo conditions and how sarcomeres adapt to the potentially increased tension. The purpose of this study was to simultaneously evaluate the fiber tension and sarcomere length in vivo, which may help us better understand biomechanical changes and sarcomeric adaptations associated with spasticity/contracture.

**METHODS:**

28 fiber bundle specimens from the tibialis cranialis (TC) muscle of 8 Sprague-Dawley rats were investigated in this study. For each specimen, a small bundle of fibers was isolated with the two ends still attached to the remaining muscle bulk. A 1 mm tube with a 45° prism at its tip to guide transmission light through the fibers was inserted underneath the bundle to illuminate the fibers and sarcomeres in vivo (Fig. 1). Sarcomere/fiber images were recorded in vivo through an objective above the fibers and a CCD camera. The tube was attached to a precision force sensor to measure the force between the prism and the fibers (Fig. 1). The fiber bundle was lifted by the tube-prism using a micrometer, and the lifting force and lifting distance were recorded by the force sensor and a linear position sensor, respectively. The evaluation was done at the 45° dorsiflexion, neutral (0° dorsiflexion), and 45° plantar flexion.

With the fiber bundle lifted at the middle, the axial tension \( F_x \) along the fiber bundle could be estimated from the lifting force \( F_y \) and lifting distance \( \Delta y \) (Fig. 2). Over the range of the lifting, the axial force was curve-fit with \( F_x = C_f e^{\Delta y} \), which was then extrapolated to \( \Delta y = 0 \) to determine the initial tension \( F_i \) at zero lift. Two blocking feet were used to prevent potential elevation of the two ends of the fiber bundle during the lifting (Fig. 3). High-definition camcorder was used to monitor the potential movement of the two fiber bundle ends. The length of the fiber bundles was measured at the 3 ankle positions (plantar flexion, neutral and dorsiflexion), which was compared to the fiber length in vitro after transactions at the two ends of the fiber bundle. Paired t test was used to compare between the groups, with the significance level at 0.05.

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F_x = \frac{F_y}{2 \sin(\theta)}
\]

\[
\theta = \tan^{-1}\left(\frac{F_y}{F_i}\right)
\]

**RESULTS:**

Fig. 4 shows the typical curve of \( F_y \) and \( F_x \) during lifting with the ankle at the 3 positions. The fiber bundle was stiffer and had higher initial tension when it was at plantar flexion (steeper curves) than in dorsiflexion. The initial tension (at 0 lift) of the fiber bundle was higher in plantar flexion (13 ± 7.08 mN) (up-shifted curves) than in dorsiflexion (9.52 ± 5.19 mN, \( p=0.01 \)) and neutral position (10.88 ± 6.13 mN, \( p=0.03 \)) (Fig 4). The in vitro length was significantly shorter than that at in vivo plantar flexion (24.36 ± 6.01%), neutral position (22 ± 6.14% shorter), and in dorsiflexion (16.92 ± 5.77%) (Fig. 4, \( p=0.001 \))

**DISCUSSION:**

We demonstrated the feasibility of evaluating fiber tension and sarcomere length in vivo. Since the fiber bundle was stretched at plantar flexion, the in vivo initial tension of the fibers under plantar flexion with no lift involved was higher than that at the other positions, the fibers were stiffer at plantar flexion, and the fiber bundle shortened gradually more after being dissecting out as the ankle was moved to plantar flexion. Potentially, similar integrated force and sarcomere length measurements as described above will allow us to investigate biomechanical changes (under higher tension, stiffer, and subject to larger shortening once the load is released) associated with spastic fibers in vivo and quantitatively, which will help us gain insight into the mechanisms underlying spasticity and motor impairment, and potentially develop more focused and effective treatment.

**REFERENCES:**