Reflex and Nonreflex Characterization of Spasticity in Children with Cerebral Palsy: Dependence of Catch Angle on Velocity

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INTRODUCTION
Spasticity, contracture and muscle weakness are commonly seen in children with cerebral palsy. Although it is commonly accepted that spasticity is characterized with velocity-dependent increase in muscle tone, it is not clear whether the commonly measured “catch” is dependent on the movement velocity. Furthermore, convenient and quantitative device/measurement in clinical setting for evaluating children with CP is essential and there is a lack of quantitative and convenient method and device to evaluate spasticity, contracture and muscle weakness in a clinical setting. Hence the aim of this study was to evaluate spasticity, contracture and muscle weakness quantitatively using our custom a Manual Spasticity Evaluator (MSE) and Handheld Tendon Tapper (HTT).

METHODS
Ten children with cerebral palsy with spasticity at the elbow joint, aged between 7 and 16 years old and a control group of 10 age-matched children, aged from 6 to 15 years old were recruited for the study. The children sit upright next to the MSE with the shoulder abducted and flexed at 75°. The forearm was strapped to the beam of the MSE with the elbow flexion axis aligned with its rotation axis. The arm was secured to a supporting brace. EMG signals were recorded from the biceps and triceps muscles using surface electrodes.

First, different levels of force were applied onto the biceps tendon by the HTT and reflex-mediated EMG and torque responses were measured. Next, the elbow was moved at a slow velocity of 30°/sec manually, guided by audiovisual feedback to measure the ROM and contracture with controlled terminal torque (0.5, 1 and 1.5 Nm) followed by higher velocities arranged at random order for evaluating spasticity and detecting the catch angle related to stretch reflex. The tapping force, reactive torque \( \tau \), joint angle, and EMG signals were sampled simultaneously at 1000 Hz for further analysis.

The reflex torque varies with the tendon tapping force. Hence the gain of the tendon reflex was determined by determining the reflex system impulse response with the corresponding system gain and threshold in tapping force. The catch angle was detected by the abrupt increase of \( d\tau/dt \) (Peng et al 2004). Mann-Whitney U test and Spearman rank correlation test were chosen for the statistical analysis.

RESULTS AND DISCUSSION
The gain of the tendon reflex with tapping force and elbow torque as system input and output respectively shows that children with CP had higher tendon reflex gain than the
control subjects (p=.005). The catch angle in children with CP was determined with 4 relevant parameters displayed simultaneously (Fig. 1). The width of the shaded area represented the movement velocity and the gradually narrowed path showed the slow down and choke during the “catch”, and the narrowest path occurred after the movement passing through a “hot spot” which stands for the abrupt increase of \( \frac{dt}{dt} \). The corresponding position of the hot spot was taken as the catch angle (Fig. 1).

The ROM of children with CP was significantly smaller than that of the control subjects at torque limits of 0.5 and 1 Nm (p<.001), but showed no difference at 1.5 Nm (p=.058). There was no difference of flexion ROMs between the groups.

The catch angle varied with the velocity considerably (7.17°±4.37°) and showed significant correlation with the velocity (correlation coefficient = .25 at \( \alpha \) level of .038, Figure 2). In other words, the catch angle occurred later during extension at higher velocities, indicating the increased resistance at higher velocities was also dependent on the position. The \( \frac{dt}{dt} \) and torque at the catch angle increased significantly with increasing velocity (p=.002 and .005 respectively). Nonetheless the passive torque at the corresponding catch angles at the different velocities was not significantly different.

**SUMMARY/CONCLUSIONS**

The current results demonstrate that (1) children with CP have higher gain in reflex component, (2) under the controlled terminal torque, the children with CP retain less range of motion toward the extension direction, (3) the sensing of the catch is contributed not only from the reflex component but also the stiffness of the activated muscle when the elbow was moved further at the higher velocities.

**REFERENCES**


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