ELECTROMYOGRAPHIC RESPONSES TO AGING IN CHILDREN WITH CEREBRAL PALSY

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INTRODUCTION

The use of surface electromyography (sEMG) recorded during the performance of a functional activity, such as gait, has provided valuable insight into motor development and changes with age in the pediatric population. [1] Muscle activation changes with age have not been reported for children with cerebral palsy (CP). A strong correlation between muscle activity and function in children with CP, as well as a decline in ambulatory status as children with CP mature into adults, has been demonstrated in previous studies [2]. Thus, changes in the sEMG indicative of such alterations in muscle activation patterns would be expected. In typically developing (TD) children, it has been reported that there are no changes in the onset and offset times of muscle activation patterns over the age of 3 years [1]. However, more detailed analysis has not been reported. Changes in signal amplitude and frequency with age should be investigated in both children with TD and with CP.

The purpose of this study was to examine age-related changes in muscle activity (time-frequency components) using established wavelet analysis techniques in a group of children with CP and a group of children with TD. It was hypothesized that changes in the age-related sEMG time-frequency characteristics would be evident in both groups, and that change in the time-frequency characteristics would be evident depending on a diagnosis of TD or CP.

METHODS

A retrospective analysis of sEMG data collected from two different study protocols was performed. In both studies, the parents of all the children signed a university institutional review board (IRB) approved consent form, and the children gave verbal assent, or written assent if over the age of seven. The data was divided into four groups, representing either an older (above the age of 7) or younger (below the age of seven) age group with either CP or TD. Data were analyzed from 24 children with TD, 16 in the younger age group (mean age 3.4, range: 1 to 6 years, 9 females and 7 males) and 8 in the older age group (mean age: 11.2, range 8 to 13 years, 5 females and 3 males). Data were also available for 26 children with CP, 14 in the younger age group (mean age 4.9, range: 2 to 7 years, 5 females and 9 males) and 12 in the older age group (mean age: 10.8, range 8 to 14 years, 6 females and 6 males). In both studies, children with CP were classified as Level II (impaired ambulation over distances) or Level III (use of assistive devices) on the Gross Motor Function Classification Scale.

The two studies from which the sEMG data were pooled both involved the analysis of the sEMG signals during gait, but focused on different sets of muscles. However, both studies had sEMG data available from the rectus femoris (RF) and the medial hamstring (MH) muscles bilaterally. For the older children, the sEMG data was acquired with the Motion Lab Systems MA-310 surface EMG recording system (Baton Rouge LA). The sEMG signals were collected at a sampling rate of 1.2 kHz, with a preamplifer gain of 20 and bandpass filtering between 20 and 350 Hz. For the younger children, the Myomonitor III (Delsys Inc., Boston, MA) was used with a sampling rate of 1.2 kHz, and a preamplifier gain of 10, and bandpass filtering between 20 and 450 Hz.

The sEMG data from the muscles were processed in MATLAB (The MathWorks Inc., Natick MA, USA). Before any analysis was performed, all raw data were low passed filtered using a 2nd order Butterworth filter with phase correction and a cutoff of 350 Hz. This was done to match the frequency ranges of the sEMG signals between the two studies. A time-frequency analysis was then performed on the sEMG data using the continuous wavelet transform (CWT) [4]. The three dimensional scalogram output of the CWT was reduced to a time-frequency curve by calculating the instantaneous mean frequency (IMNF) for each 0.1% cycle interval. A functional principal component analysis (PCA) was completed using the IMNF curves from all gait cycles to assess if the muscle IMNF curves across the four groups differed, and at what points in the gait cycle. Overall differences between groups pre and post surgery were tested using a Welch statistic, while individual groups differences were assessed using Tamhane's T2 multiple comparison test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Figure 1 shows the comparison in activation between the RF and MH muscles in the four groups. The PCA was able to account for 97 to 99% of the variability between groups. The IMNF curves for the RF muscle were statistically different between all groups ($p<0.001$). The IMNF curves for the MH muscle were statistically different between all groups ($p<0.001$) except for the CP young and old group comparison, which indicated no difference ($p > 0.285$)

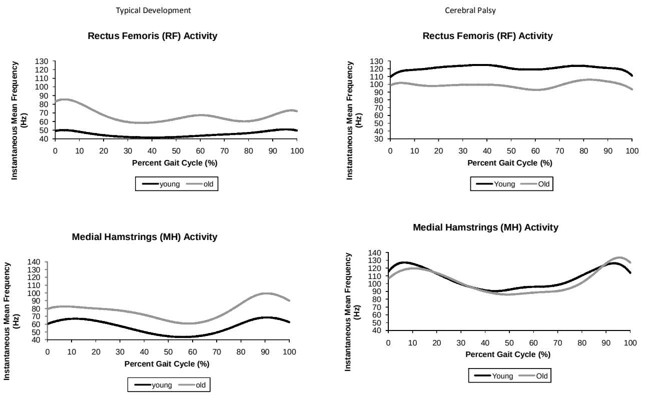

Figure 1 - Comparison of RF and MH activity for the children with CP and TD in the young and old age groups

As a function of age, the older children with TD for the RF and MH muscles exhibited an increase in the IMNF curve, with less variable activation times. This may represent increased rate coding of motor unit activation, or increased number of motor units recruited. These activation characteristics would most likely result in a larger magnitude muscle force generated which would be required to move or stabilize the older child's larger body segments during gait. This is in contrast to the RF muscle in the child with CP, where it appeared that at a younger age the objective was to activate the muscle maximally and continuously, and that with learning and maturation a relatively more synchronous pattern was developed, but was still less synchronous than the TD patterns. This would need to be explored further in a longitudinal study with the same group of individuals.

The MH muscle, in contrast to the RF, exhibited a fairly consistent pattern of activation in the child with CP regardless of age. In addition, the activation level was much higher in children with CP than the child with TD regardless of age. Given the well-documented finding of spasticity in the hamstrings in children with CP, the muscle's force generating capabilities may be impacted and greater activation necessary to offset the relative mechanical inefficiency or increased co-contraction of antagonist muscle groups in children with CP. Further, the higher activation levels may mask or negate measureable age-related changes in activation patterns of this muscle.

One limitation of this study is that the EMG data for the two groups were collected with two different systems, and although off line corrections were made to the data to allow for frequency comparisons, the possibility still exists that the systems used influenced the results. In addition, the results of this study need to be taken with caution given the retrospective nature of this study. A prospective study of these muscles in a group of children with a wider age range, and using the same data collection system is warranted to determine if the trends reported here remain.

REFERENCES

1. Sutherland DH, et al. The development of mature gait. *J Bone Joint Surg Am*, **62(3):**336-353, 1980.
2. Rosenbaum P, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl*, **109**:8-14, 2007.
3. Lauer RT, et al. A time-frequency based electromyographic analysis technique for use in cerebral palsy. *Gait Posture*, **26(3):** 420-427, 2007.

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