A FREQUENCY-BASED ELECTROMYOGRAPHIC INDEX FOR USE IN CEREBRAL PALSY

Richard Lauer[1], Carrie Stackhouse[1], Brian Smith[1], Patricia Shewokis[1, 2], Carole Tucker[1], James McCarthy[1]

[1] Shriners Hospitals for Children, Philadelphia, PA, USA
[2] College of Nursing and Health Professions, Drexel University, Philadelphia, PA, USA
Email: rlauer@shrinenet.org

INTRODUCTION

Surface electromyography (sEMG) is a typical part of instrumented gait assessment for the child with cerebral palsy (CP). Numerous methods exist to characterize the sEMG in order to gain insight into the neuromuscular impairments that exist in CP, including the use of muscle onset and offset and amplitude. However, these methods have focused upon one aspect of the sEMG to characterize the signal. The sEMG could potentially be better utilized clinically if multiple characteristics are examined concurrently. The introduction of time-frequency analysis provides a method of extracting more information from the sEMG in CP (Lauer et al 2005), and thus potentially gaining further insight into the neuromuscular system. The purpose of this study was to apply these techniques to the analysis of sEMG during gait in children with CP to derive an index that may be used to track and categorize muscle activity.

METHODS

A retrospective study was conducted with 33 children. The group consisted of sixteen children with typical development (TD) to act as a control group (mean age 10.8 years, age range: 7-14 years). The remaining data set consisted of five children with spastic, hemiplegic CP and 16 children with spastic, diplegic CP (mean age at 10.4 years, age range: 6-20 years).

The sEMG signals were acquired during a standard gait analysis as individuals walked across a 10 meter (28 foot) walkway barefoot at a self-selected pace. The activity of the following muscles was recorded bilaterally: the vastus lateralis (VL), the medial hamstring (MH), the medial gastrocnemius (MG) and the tibialis anterior (TA). A representative time-frequency pattern was extracted from the sEMG for each muscle using the continuous wavelet transform applied using the Morlet wavelet with a linear scale of 1 to 126. The result of the analysis, the scalogram, for each trial for each muscle was averaged and the representative value of the scalogram at each gait interval was calculated using the instantaneous mean frequency (IMNF) (Lauer et al., 2005).

The resulting IMNF curves were plotted as a series of muscle-muscle plots representing interlimb muscle symmetry (right versus left side) and intralimb muscle co-activation. Analysis of the muscle-muscle plots was performed using functional data analysis (FDA) techniques (Ramsay and Silverman 2005). The FDA was selected for use as it allowed for a principal component analysis of the entire plot, allowing for better assessment the of sEMG characteristics. The harmonic output from the FDA, after normalization using the values from the control group, was used to generate the index.

The EMG index was compared to several kinematic measurements, a Gait Index, (Schutte et al., 2000) and several clinical assessment scales. Correlations were performed using either Pearson Product Moment or Spearman's rho with a two-tailed test for a 0.05 significance criterion. Normality of data was assessed and confirmed using the D'Agostino-Pearson test for normal distribution. In addition, 95% confidence intervals were calculated.

RESULTS AND DISCUSSION

The EMG indexes demonstrated an increase in the value with an increasing level of motor impairment. On an initial breakdown of the groups into children with spastic, hemiplegic CP (Hemi), and children with spastic, diplegic CP grouped according to their GMFCS level (Palisano et al., 1997), Level 1, Level 2 or Level 3, the average scores (STD) were as follows: Hemi: 13.23 (4.5); Level 1: 15.6 (3.5); Level 2: 16.5 (14.2); Level 3: 52.41 (28.8). No distinction at this time is made between right and left hemiplegia given the small sample size and the variability in the data.

Table 1: Correlation analysis with upper and lower limits confidence intervals for *r* for the EMG index (**p < 0.01**, *p <0.001).*

	EMG Index	
Measure	**r**	**95% CI**
Cadence	*-0.74*	-0.89 to -0.46
Step Length	-0.38	-0.70 to 0.06
Velocity	**-0.62**	-0.83 to -0.25
Gillette Index	**0.62**	0.26 to 0.83
GMFCS	**0.65**	0.30 to 0.84
GMFM-D	**-0.70**	-0.87 to -0.38
GMFM-E	**-0.65**	-0.85 to -0.31
POSNA-Global	-0.36	-0.69 to 0.08
POSNA_Mobility	**-0.43**	-0.73 to 0.01

The correlation analyses between the EMG index and the selected kinematic parameters and clinical assessment scales are summarized in Table 1. In addition, represented are the upper and lower limits for the 95% confidence interval. For the index, significant moderately high (r = -0.43 to -0.74 and r = 0.56 to 0.65) correlations were achieved for all parameters and scales compared except for step length (r = -0.38) and the POSNA global score (r = - 0.36).

SUMMARY/CONCLUSIONS

A new method of processing the sEMG data acquired during a standard gait analysis, and reduction of the data to a meaningful scale has been described. The end stage of the analysis, an EMG index, correlated significantly to existing clinical measurements of motor impairment in cerebral palsy. This methodology has the potential to provide additional insight into the outcome of a clinical intervention that was not available previously, and may find use as a predictive tool that can be utilized for clinical decision making. Future avenues of investigation for this scale involve refinement of the index to determine sensitivity to spasticity, muscle weakness, and fatigue, as well as testing on prospective data to examine reliability.

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