Ultrasound Echotexture Analysis of the Tibialis Anterior Muscle during Isometric Contraction in Children with Cerebral Palsy and Healthy Controls

B. Dougherty[1,2], A. Eranki[1], L. Curatalo[3], D. Damiano[3], and S. Sikdar[1]
[1]George Mason University, Fairfax, VA, [2]University of Virginia, Charlottesville, VA, [3]National Institutes of Health, Bethesda, MD

Introduction: Cerebral palsy (CP**)** is a neurodevelopment disorder that may be associated with secondary muscle pathology including muscle weakness and/or reduced functional ability. Ultrasound is an important clinical tool that could be used to better assess and understand musculoskeletal function in patients with CP. The goal of this study was to investigate whether quantifying, through texture analysis, the ultrasonic backscattered echo of muscles during relaxation and maximum voluntary isometric contraction (MVIC) may provide insight into muscle function in children with CP.

Materials and Methods: Ultrasound images of the *tibialis anterior* muscle were acquired from 5 children with CP (Gross Motor Function Classification Scale level I & II) and 5 healthy volunteers of similar age range (data were collected twice for each healthy volunteer) using an Ultrasonix Sonix Touch system (Richmond, BC, Canada) and a 5-14 MHz transducer. Data from patients with CP were collected at 1, 4 and 7 months following therapeutic intervention using functional electrical stimulation (WalkAide, Innovative Neurotronics, TX, USA). The *tibialis anterior* muscle was imaged in cross section during relaxation and MVIC in both groups. Using the envelope of the ultrasonic backscattered echo, quantitative texture analysis was performed using several techniques to yield ten variables: speckle factor (SF) with and without gamma kernel density estimators (GKDE) as a measure of scatterer density, entropy as a measure of heterogeneity, speckle statistics described using the m and omega parameters of the Nakagami distribution calculated using GKDE or maximum likelihood estimation, the average and standard deviation of the normalized backscatter, and the signal-to-noise-ratio. Both during relaxation and MVIC, parametric images were obtained using a sliding window for each image; parameter values were extracted from inside the *tibialis anterior* for further analysis. Principal component analysis (PCA) was used to determine the variables accounting for the most variance in the data.

Results and Discussion: Entropy and SF were the largest contributors of the first two principal components and were used for further analysis (Fig. 1A). SF is indicative of the underlying scatter density of the imaged tissue such that an increase in SF signifies a decrease in the underlying scatter density. However, entropy, which indicates the randomness or disorder of the data set, decreases with a decrease in the underlying scatter density and heterogeneity of the muscle. The percent change in SF and entropy between the relaxed and contracted muscle were calculated for each patient and time point. SF showed a decreased percent change between healthy (n = 9) and CP patients at month 1 (n = 5) from a mean of 1.69% to –0.29%, normal and CP patients respectively. Measurements at 4 (n = 5) and 7 (n = 4) months show an increase in the percent change of SF from 0.17% to 0.90% toward the normal value of 1.69% (Fig. 1B). Entropy showed an increased percent change from normal to CP patients at month 1 from a mean of -1.25% to 1.10%, normal and CP patients respectively. During treatment, CP patients at months 4 and 7 show a decrease in percent change of entropy from 0.25% to 0.11% toward the normal value of -1.25% (Fig. 1C). Statistically significant changes were seen between SF Normal and 1 month.

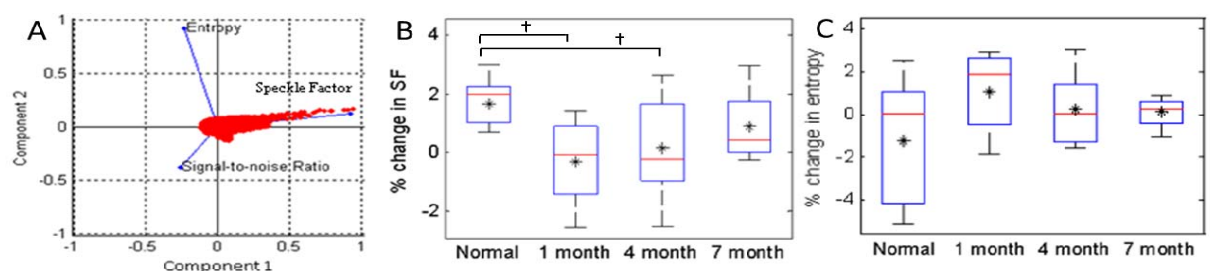

Figure 1. Panel A displays PCA where, SF and entropy are the largest contributors of variance in the given data set. The percent change in SF (Panel B) and entropy (Panel C) of children with CP approaches the normal values following intervention with functional electrical stimulation. († indicates a statistically significant change where $p < 0.05$).

Conclusion: The preliminary texture analysis of the *tibialis anterior* muscle during relaxation and MVIC indicates that SF and entropy account for the greatest amount of variance in our small study sample. Further analysis is needed to determine the relationship between quantitative texture measurements and muscle function. Texture analysis may be useful for quantifying muscle function in conjunction with current clinical and functional gait measures.