Gait Kinematics and Muscle Activity from Wearable Sensors in Persons with Multiple Sclerosis

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Introduction

- Multiple sclerosis (MS) is an unpredictable, often disabling disease of the central nervous system that disrupts the flow of information within the brain, and between the brain and body. Symptoms range from numbness and tingling to blindness and paralysis.
- The course of MS is highly varied and unpredictable. In most patients, the disease is characterized initially by episodes of reversible neurological deficits, which is often followed by progressive neurological deterioration over time[1].
- In this study, we are developing statistical models for tracking mobility impairment indicators of symptom progression using the concepts from signal processing to help to stop the progression of disease in their early stage.
- The correlation between falling risk during gait cycles and parameters including acceleration, angular velocity, and electromyography (EMG) will be built to predict the possible treatment of MS.

Figure 1. BioStampRC wearable sensor provides raw kinematic data from the built-in accelerometer and gyroscope

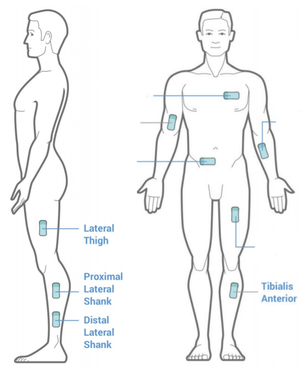

Figure 2. Wearable sensors attached to Tibialis Anterior and Proximal Lateral Shank to collect angular velocity and sEMG data

Methods

- 8 patients with MS were recruited from the UVM Multiple Sclerosis Clinic
- Subjects were instrumented with wearable sensors (BioStampRC - MC10, Inc., Lexington, MA) (Figure 1) while performing a series of clinical assessments and tasks designed to mimic daily life.
- We consider the angular velocity (Sampled at 125Hz) of the shank and surface electromyographic (sEMG) data (Sampled at 500Hz) from the anterior tibialis to quantify each subject's gait characteristics during a 1-minute bout of walking at a comfortable pace.
- EMG signal was filtered by 4th order Butterworth filter with upper and lower limit of 20 and 10 Hz respectively as well as rectified to extract signal envelope[2]. Angular velocity data were filtered using a 10th order median filter, and a wavelet-based approach (Figure 3) was used to identify heel-strike events.
- Twenty gait cycles were extracted and averaged for each subject to yield representative kinematic and muscle activity patterns.

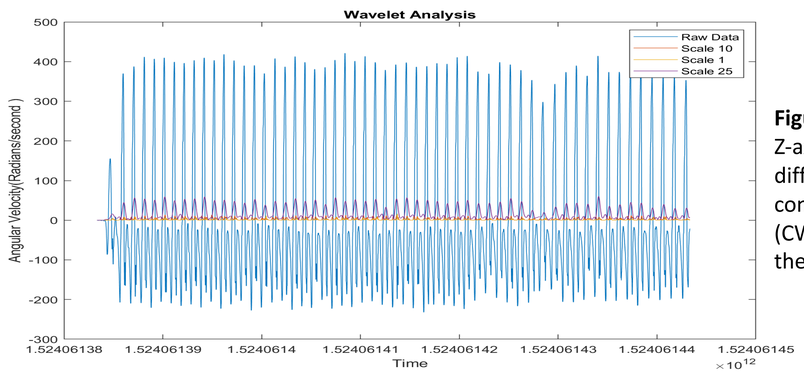

Figure 3. Wavelet Analysis for Z-axis angular velocity: different scale values in the continuous wavelet transform (CWT) was used to determine the best gait cycle detection.

Results

The Pearson rank correlation test produced rho value of 0.9510 with p-value of 0.0129 between the first peak timing and Expanded Disability Status Scales (EDSS), and rho value of 0.9155 with p-value of 0.0291 between the second peak magnitude and EDSS. Both results (Table 1) showed a strong correlation with great significance ($p < 0.05$). The gait cycle analysis is shown as Figure 4.

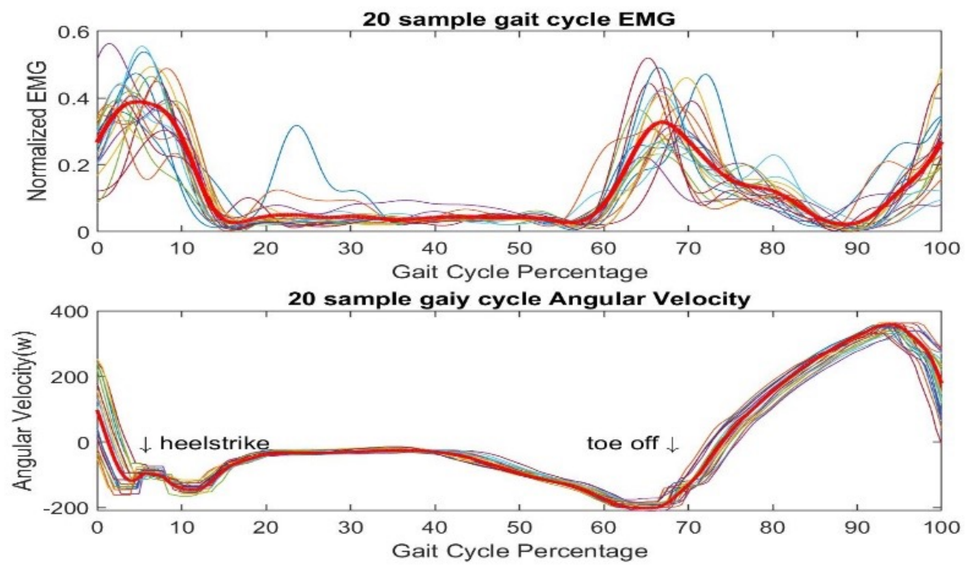

Figure 4. 20 samples of gait cycle EMG signal and angular velocity in one gait cycle for subject one. The average of 20 samples is highlighted with the red bold line.

Pearson Rank Correlation	rho Value			p Value		
Clinical Test	ABC	MSWS	EDSS	ABC	MSWS	EDSS
Peak1 Height	-0.49879	0.871967	0.598158	0.392335	0.053926	0.286635
Peak1 Timing	-0.52188	0.796397	**0.951015**	0.367051	0.106852	**0.012919**
Peak2 Height	-0.43378	**0.915473**	0.606691	0.465538	**0.029124**	0.277963
Peak2 Timing	-0.30035	-0.63782	-0.47593	0.623407	0.246941	0.417748

Table 1. Pearson Rank correlation results between peak height and time with Activities-specific Balance Confidence Scale(ABC), Expanded Disability Status Scales (EDSS) and Multiple Sclerosis Walking Scale (MSWS): highly correlated data is highlighted by blue cells

Discussion

- The strong correlation between the EMG data and clinical test results helps us better understand the characteristics of the Multiple Sclerosis.
- Using the results from this study, future study will be able to predict the falling risk and probability after collecting the long-term (24-36 hours) EMG data.
- We were only able to study the subjects who were in their early stage of MS. For patients who are in the more progression symptom, we need a better approach to collect data and provide a solution for them.
- National MS society allocated $12 million dollars to the MS research and treatment to restore function and treat MS[3]. Work done in this study will provide a statistical reference to other MS studies.

Conclusions

The current study focused on the characterization of patients with MS and provided positive correlation indicators. Future study will compare the healthy subjects with the subjects in this study to further characterize the difference in their EMG signal during the gait cycle.

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