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

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Introduction: Multiple Sclerosis (MS) is a neurodegenerative disease associated with progressive demyelination and axonal damage throughout the central nervous system. This damage results in symptoms including impaired coordination, muscle strength, and sensation, all of which lead to problems with balance and postural control especially during dynamic activities. Current approaches for capturing these symptoms are largely qualitative and involve a variety of patient self-report measures. With the advent of new wearable sensors, there is an interest in developing new approaches for objectively quantifying symptoms in MS so as to improving tracking of their progression and response to intervention. Here we examine the use of a novel, multi-modal wearable sensor for capturing gait characteristics associated with MS-induced disability and mobility impairment.

Methods: Five subjects with MS were recruited from the UVM Multiple Sclerosis Clinic and completed the IRB-approved protocol. Each subject completed the Multiple Sclerosis Walking Scale (MSWS-12), a standard self-report measure of MS-induced walking impairment, and their MS-induced disability was characterized according to the Expanded Disability Status Scale (EDSS). Prior to completing a series of functional assessments, each volunteer was instrumented with wearable inertial and biopotential sensors (BioStampRC - MC10, Inc.) set to record angular velocity and surface electromyography (sEMG) data at rates of 125 and 500 Hz, respectively. Herein we consider shank angular velocity and anterior tibialis sEMG data from a 1-minute bout of walking at a comfortable speed to identify signal characteristics associated with walking impairment, as characterized by the MSWS-12, and MS-induced disability, as characterized by the EDSS. To this end, the sEMG data were processed according to standard techniques to extract the signal envelope normalized based on a subject's maximum voluntary contraction. The angular velocity signals roughly orthogonal to the sagittal plane were smoothed with a 10-point median filter and used to detect heel strike and toe off events using a standard wavelet-based approach. Events were used to partition the angular velocity and sEMG data into individual gait cycles (e.g., see Fig. 1). Twenty gait cycles were extracted and averaged for each subject to yield representative kinematic and muscle activity patterns. These patterns were parameterized by extracting the timing and magnitude of the first (around 5% of the gait cycle in Fig. 1) and second (around 68% of the gait cycle in Fig. 1) peak in the sEMG signal and of the maximum angular velocity values during swing and stance. Pearson product moment correlation was used to identify associations between these parameters and MS-induced disability and walking impairment via comparison with the EDSS and MSWS, respectively.

Results and Discussion: Pearson product moment correlation revealed significant association bettween several kinematic and muscle activity parameters and the MSWS and EDSS clinical scores. Specifically, delay of the maximum angular velocity during stance ($r = 0.96$; $p = 0.01$) and increase of the first sEMG peak ($r = 0.92$; $p = 0.03$) were each associated with increased walking impairment (i.e., increased MSWS score). Similarly, delay of the first sEMG peak ($r = 0.95$; $p = 0.01$) was associated with increased MS-induced disability (i.e., increased EDSS score). These results suggest that

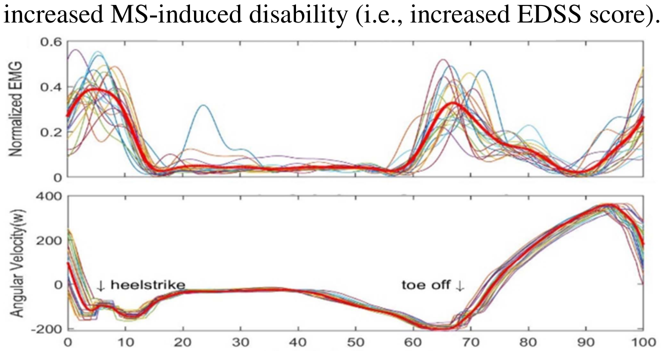

Figure 1. sEMG (top) and angular velocity (bottom) measured during 20 gait cycles of a representative subject and reported as a percentage of the gait cycle. Heel strike and toe off events are annotated for reference. The average sEMG and angular velocity profiles are shown as bold red curves.

Conclusion: The current study indicates that multi-modal wearable sensors may provide a means for objectively quantifying alterations in gait kinematics and muscle activity patterns associated with MS symptoms. Future studies will confirm these findings in a larger sample of persons with MS.