Spring 2023 Research Summary
Research Advisors: Dr. Evy Meinders & Dr. Eni Halilaj
Ryan Nagle

Rationale:

Electromyography (EMG) is a measurement used to quantify muscle activation. EMG sensors placed on the surface of the skin detect the electrical activity produced when a muscle contracts in response to stimulus from the nervous system.[1] The EMG signal is often used to assess the muscular function of athletes and rehabilitation patients. The EMG signal provides information about muscular activation and sequencing during movement and the generation of muscular fatigue. Differences in these measurements provide clinicians or coaches with valuable insights that may lead to the improvement of clinical outcomes or performance.[2] Currently, lab grade EMG sensors cannot be used in natural environments because they are expensive, difficult to use, and time-consuming to set up. To address these shortcomings, companies like Myontec have developed EMG sensors built into clothing. However, these sensors have not yet been extensively tested against lab grade sensors.

In this project, Myontec MShorts 3, a textile EMG device, will be validated against Delsys, a lab grade sensor before and after a fatiguing protocol during walking, running, and strength exercises (Romanian deadlift and front squat).

Approach:

The first few weeks of this project focused on gaining familiarity with the Myontec, Delsys, and the muscular fatiguing process. Preliminary walking and running data was collected using a similar EMG sensor setup to the final data collection. After this data was collected, code for the alignment and segmentation of the EMG data was written using MATLAB. Within the MATLAB code, the data are aligned, filtered, rectified, and normalized (by a max value throughout the trial), then the data is segmented and plotted. The filtering code used was an adapted version of code written by previous students within the lab.

Alignment is the process in which peaks in the vertical acceleration (produced by the subject hopping before and after the activity) are used to ensure that the Myontec and Delsys EMG signals are synced temporally. Segmentation is the process in which the EMG data is cut into segments based upon the start and end points of each gait cycle for better analysis. Peaks in vertical acceleration data can be used to determine when a subject is at the toe-off stage of gait because during toe off the body accelerates upwards.[3] These EMG segments are then time-normalized to account for small differences in gait cycle length and averaged to produce a graph of the average muscle activation during a gait cycle.

Fatigue can be quantified by measuring the decrease in the median frequency of the EMG signal over time.[4, 5] This change is highly correlated with decreased conduction velocity in the muscle fiber, which is a direct result of the accumulation of H+ ions during fatigue.[5] Code was written to calculate the median frequency using a fast fourier transform. The pre- and post-fatigue data were compared by calculating the percent difference from the pre- to the post-fatigue condition for running, walking, and during the strength exercises.

The preliminary dataset was used to test the alignment and segmentation code to ensure that it was working properly. After this stage was completed, a fatiguing protocol was written and we began data collection. EMG sensors were placed on the vastus medialis, rectus femoris, vastus lateralis, semitendinosus, and the biceps femoris according to SENIAM guidelines.[6] The markers for motion capture were placed based upon a modified version of the Rizzoli markerset (standard arrangement used by the lab). Two trials separated by one week were collected using the testing and fatigue protocol below.

Pre- and Post-Fatigue Testing: 1 set of each of the following movements (separated by three small hops for alignment):

- Measure max vertical jump on force plate
- Bilateral weighted Front Squat (5 reps)
- Weighted RDL (5 reps)
- Walking (comfortable pace of 1.3m/s – 1 minute)
- Running (comfortable pace of 2.5m/s – 30 seconds)

Quad and Hamstring Muscular Fatigue Protocol (adapted from Padua et al) :
22kg Barbell-loaded back squat onto a box (~⅓ of BW)

- Squat onto a box (~60 degrees of range of motion) at a rate of 30 squats per minute (60bpm metronome) until the subject falls 4 squat cycles behind the set pace or fails to complete 2 successive squat cycles

**During trial 1, a 20kg kettlebell substituted was for a barbell to load the squat because it was easier to acquire and transport. However, this form of loading resulted in the lower back and upper body reaching failure prior to the lower body. In trial 2, a barbell was used to make the lower body the limiting factor and to more closely mimic the Padua et al protocol.

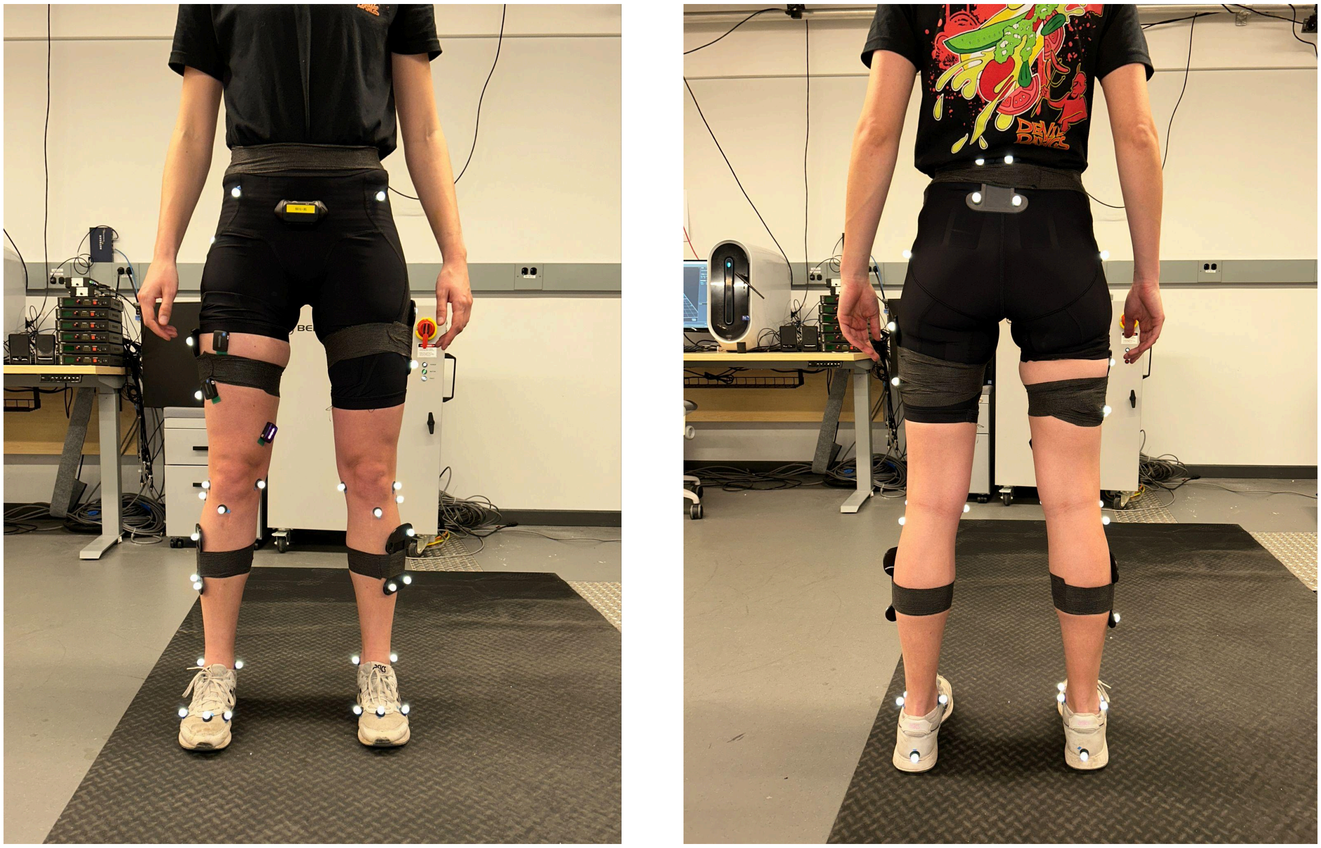

Figure 1: Sensor and Marker Placement on Front and Back of Subject

Results:

Overall, it appears that the Myontec device measures similar levels of muscle activation to the Delsys. The data appear to have peaks of similar amplitude, excitation bursts of similar lengths, and peaks at similar locations within the gait cycle (Figures 2, 3, 4). It is unclear as to whether fatigue can be accurately and consistently measured using the Myontec device as the data are inconsistent in the Delsys lab grade sensor between trial 1 and trial 2. For instance, the median frequency of the vastus lateralis decreased by 6.1% in trial 1 while it increased by 7.2% in trial 2 (Figure 5). These discrepancies likely result from the many issues with fatiguing protocols, including the subjective nature of fatigue and the willingness of the subject to push to complete failure. Interestingly when comparing the Myontec to the Delsys, similar overall trends were observed. The Myontec percent difference roughly agrees with the average of the Delsys percent difference. However, the conclusions that can be drawn from a single subject are understandably limited. The below graphs (Figures 2, 3, 4) are normalized based upon the maximum value of each muscle during running prior to the fatiguing protocol. Due to temporal syncing issues with certain Delsys sensors, the quad activation during trial 1 and the hamstring activation during trial 2 are not accurate when to graphs within the literature. Additionally, the vastus medialis sensor fell off during walking after the fatiguing protocol and the rectus femoris had an poor signal to noise ratio during running in trial 2.

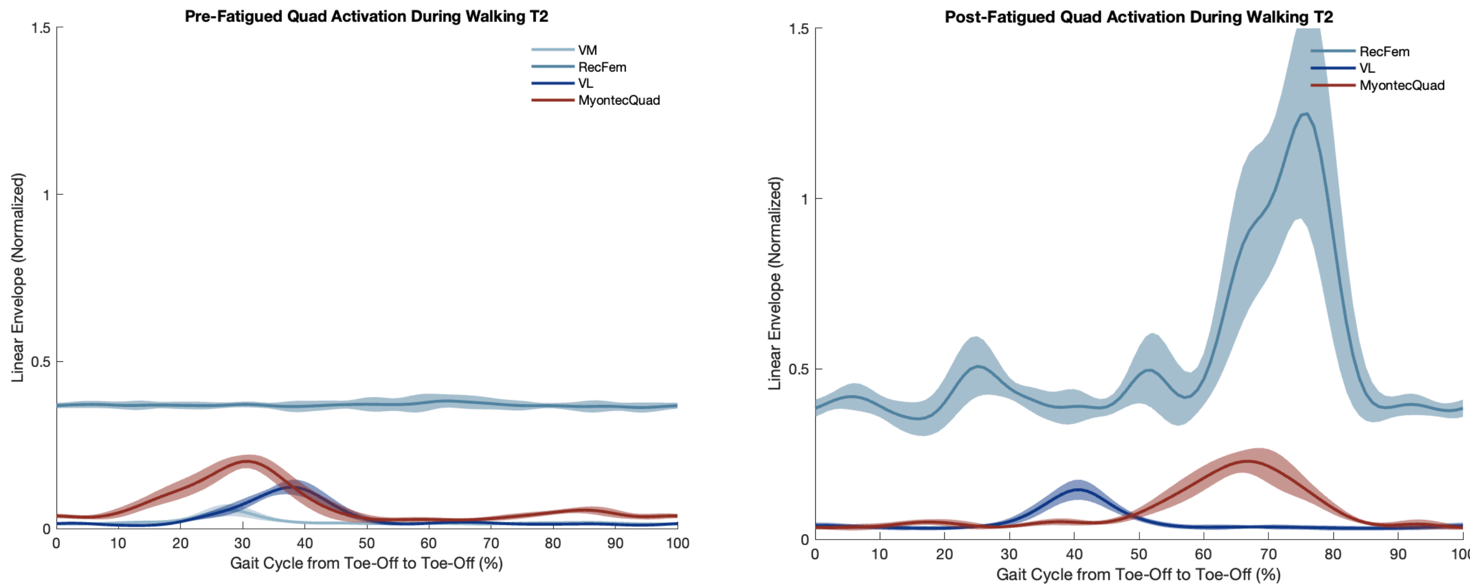

Figure 2: Pre- and Post-Fatigue Quad Activation During Walking in Trial 2

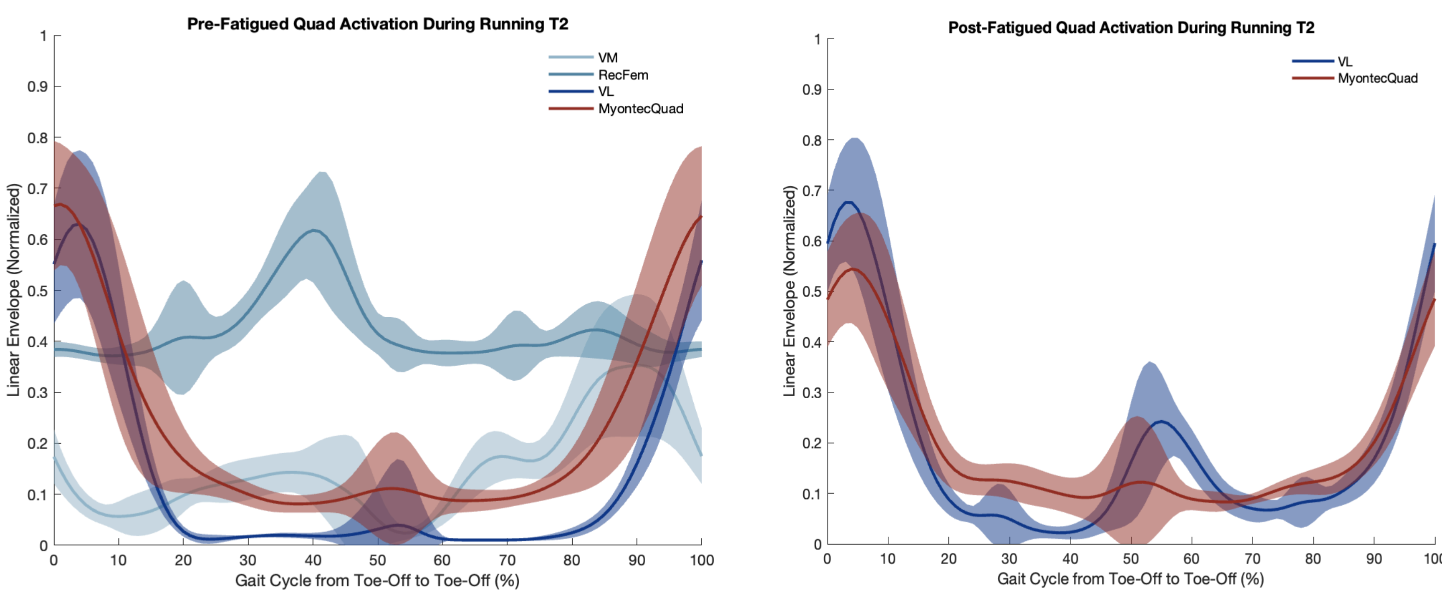

Figure 3: Pre- and Post-Fatigue Quad Activation During Running in Trial 2

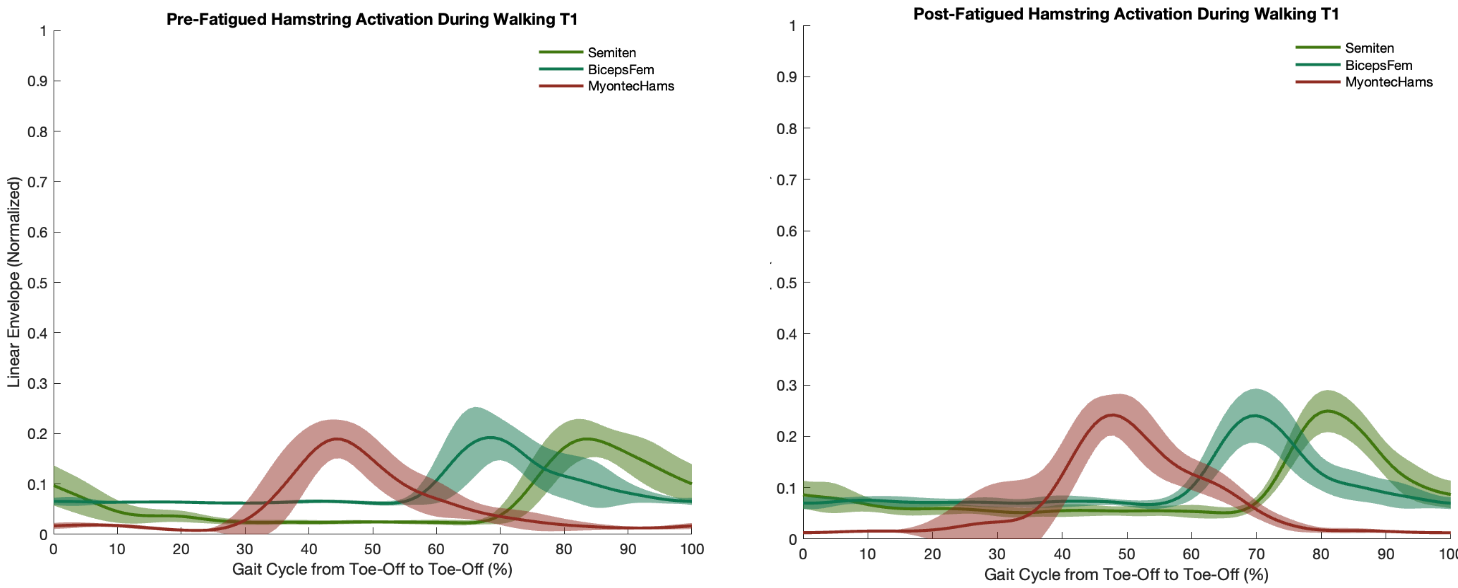

Figure 4: Pre- and Post-Fatigue Hamstring Activation During Walking in Trial 1

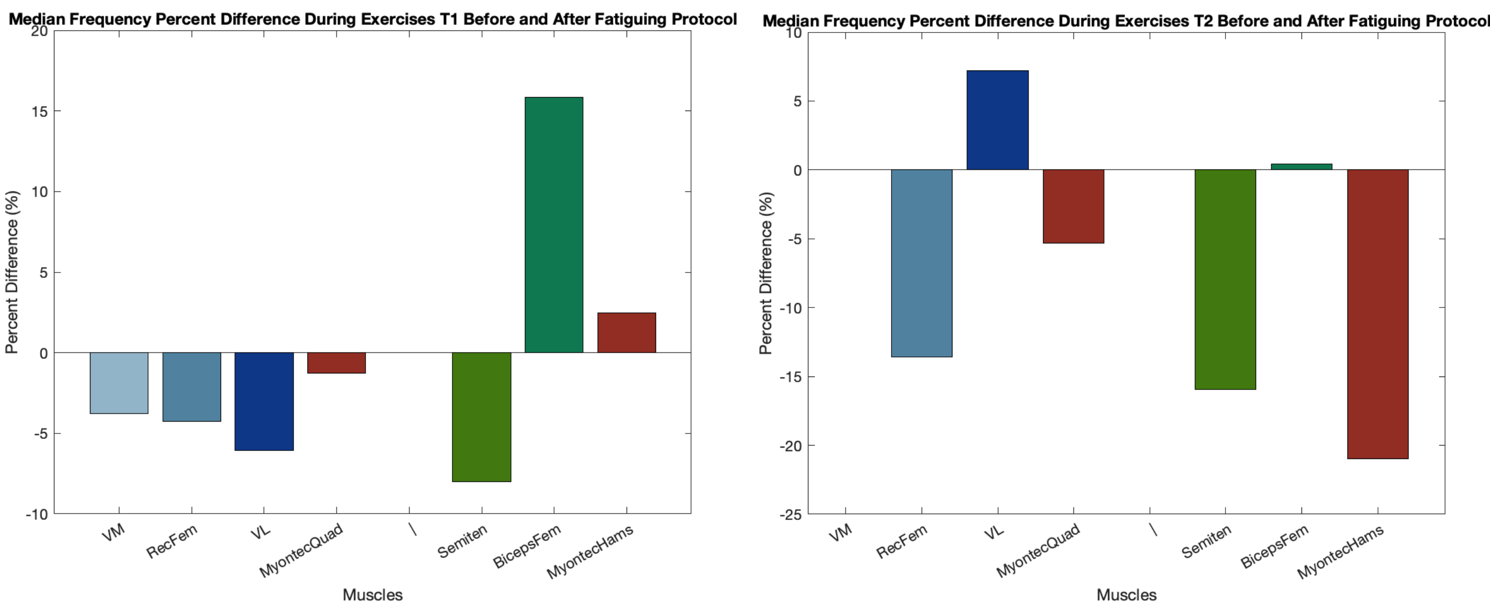

Figure 5: Median Frequency Percent Difference During RDL and Front Squat After Fatiguing Protocol

Technical Setbacks:

The first technical setback that we encountered was the alignment of Myontec acceleration data with Delsys. The sampling rate of the Myontec data was reported to be 25 Hz for the IMU and 1000 Hz for the EMG on the specifications sheet. However, the true sampling rates ended up being around 21 Hz and 840 Hz respectively. This forced the alignment and segmentation code to be written independently of the provided sampling rate. As a result, both the beginning and end hop test peaks were used to sync the data correctly.

The next technical setback related to the synchronization of the Delsys sensors. During the first collection Delsys sensors 1-5 were used. Once the data were plotted, sensor 1 appeared to be delayed by approximately half a gait cycle when compared to the other Delsys sensors. After this was discovered, we used sensors 3-7 for the second collection. After processing this data, sensor 6 appeared to be off by roughly half a gait cycle also. This unfortunately limited which graphs were usable for our comparison. We believe this is the result of using the Delsys sensors in conjunction with the iPad over bluetooth instead of with a computer.

Conclusion:

In conclusion, this project was successful in preliminarily identifying the similarities and differences between the Myontec and Delsys EMG. Additionally, the code that was written will greatly streamline the process for future data analysis and comparison of these two sensors. This research was a critical first step towards the future of monitoring of rehabilitation patients and athletes within natural environments. For future collections, a computer should be used in conjunction with the Delsys to resolve the syncing issues and the hop test should be performed with more time between hops (to allow for easier alignment and post-processing). Additionally, an objective measure of fatigue like max jump height should be included to instantly verify that the subject has reached an adequate level of fatigue. In the future, more data should be collected across different subjects to allow for more statistical power to fully validate the Myontec EMG sensor against the lab grade Delsys EMG sensor.

References:

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