Determining if lower leg muscle activation can be a significant predictor of sprint performance speed

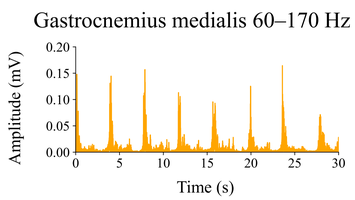
Sami Benchaaboun
Mentored by Jarick Cammarato

Introduction

Surface electromyography (sEMG) measures the electrical signals produced when motor units within a muscle are activated (Figure 1). A common method for analyzing EMG data is the root mean square (RMS), where higher RMS values indicate stronger muscle contractions. Prior research shows that RMS can assess fatigue and exercise intensity in lower extremity muscles such as the tibialis anterior (TA) and gastrocnemius medialis (GM) (Chai et al., 2019). Furthermore, shifts in EMG frequency reflect differences in fast-twitch (type II) and slow-twitch (type I) fiber recruitment under fatigue, as type I fibers are increasingly activated when type II fibers fatigue (Hegedus et al., 2020).

The GM contains a relatively even mix of type I and II fibers, while the TA has a higher proportion of type II fibers (~60%). Type II fibers enable the rapid, forceful contractions required during sprinting, with the GM producing plantar flexion for horizontal force and the TA stabilizing the ankle and absorbing impact at heel strike. Strengthening these muscles through calf and toe raises may enhance sprint performance. This study examined whether RMS activation in the TA during toe raises and in the GM during calf raises was linearly related to 100-meter dash time (referred to as sprint times) in high school participants. A strong negative linear relationship was hypothesized.

Figure 1 (right): An example of what the filtered output of the EMG signal taken from the GM of one participant when it is filtered and split into the frequency bands. This was specifically the 60–170 Hz signal. Each peak represents the activation of the GM. This was generated using Python.



Materials and Methods

The participants were high school students (n = 28, M = 16 years, SD = 1.1). Prior to testing, participants completed a consent form and provided preliminary data, including height, weight, age, self-reported activity level (1–10), sports played, and average daily moderate to vigorous cardio.

Testing occurred over three days: the EMG data was collected from the GM on the first day, from the TA on the second day, and sprint times on the third day. Before testing on the first two days, the skin over the GM and knee was cleaned with a rubbing alcohol wipe, and electrodes were placed (Figure 2). The same was done for the TA (Figure 3). EMG data was recorded using the Vernier Go Direct EKG sensor at the max sampling rate of 400 Hz, each set lasting 30 seconds.

Materials and Methods (continued)

The first testing day involved calf raises, where participants held an elevated position (Figure 2) for two seconds, rising as high as possible to ensure muscle activation, before returning to a neutral position for two seconds, repeating this cycle for 30 seconds per set. Participants completed as many sets as possible until they could no longer maintain proper form or timing, following along with a 60 beats-per-minute metronome used to ensure consistency. The second day followed a similar structure with toe raises, using five-second holds in both the raised position (Figure 3) and the neutral position, continuing until failure under the same criteria. On the final day, participants' sprint times were recorded after a warm-up consisting of a 400-meter jog at a moderate pace followed by 10 forward and side lunges.

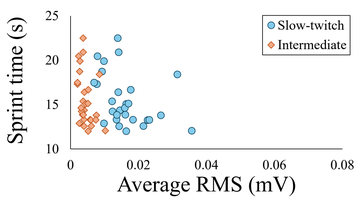
EMG data from 28 participants were processed in Python. The RMS of peak amplitudes was calculated for each set and then averaged within and across sets. Signals were band-pass filtered into 20–60 Hz (slow-twitch) and 60–170 Hz (intermediate fast-twitch; Figure 1)

Figure 2 (left): Electrode and lead wire placement used to record EMG activity from the gastrocnemius medialis during the calf raise exercise.

Figure 3 (right): The wire and electrode placement to capture the EMG signal from the tibialis anterior during the toe raise exercise.

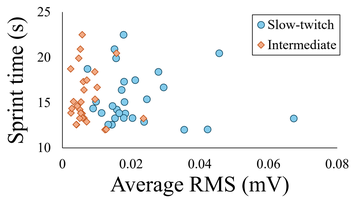
Results

Gastrocnemius medialis average RMS vs. sprint time



Graph 1 (above): Average RMS (mV) of the GM EMG signal across muscle-fiber types. Slow-twitch fibers showed the highest RMS, indicating greater activation than the other band.

Tibialis anterior average RMS vs. sprint time



Graph 2 (above): Average RMS (mV) of the TA EMG signal by muscle-fiber type. Slow-twitch and intermediate bands showed similar RMS values.

Results (continued)

Two multiple linear regression analyses were conducted to examine whether average RMS amplitude (mV) in the GM and TA was associated with sprint time (M = 15.51 s, SD = 2.87). For the gastrocnemius medialis, RMS activation in the slow-twitch (M = 0.02 mV, SD = 0.007) and intermediate (M = 0.005 mV, SD = 0.002) components was not a significant predictor of sprint time, R^2 = .151, $F(2, 25) = 2.23$, p = .129. Similarly, tibialis anterior RMS activation in the slow-twitch (M = 0.02 mV, SD = 0.01) and intermediate (M = 0.007 mV, SD = 0.004) components did not significantly predict sprint time, R^2 = .118, $F(2, 25) = 1.67$, p = .208.

Conclusion

The purpose of this study was to examine whether activation of the gastrocnemius medialis (GM) and tibialis anterior (TA), measured using the RMS of EMG amplitude values, was related to sprint time in high school participants. The results showed no relationship between either GM activity during calf raises or TA activity during toe raises and sprint time, suggesting that both muscles may play a limited role in sprint performance.

Overall, these findings do not support the original hypothesis. However, GM and TA activation patterns may still contribute to sprint performance. These findings highlight the value of surface EMG (sEMG) as a tool for evaluating muscle activation in relation to performance. Future research should investigate additional muscles, use EMG systems that have a higher max sampling rate, better control confounding variables, and increase the number of trials to improve reliability.

References

Chai, G., Wang, Y., Wu, J., Yang, H., Tang, Z., & Zhang, L. (2019). Study on the recognition of exercise intensity and fatigue on runners based on subjective and objective information. *Healthcare*, *7*(4), 150. https://doi.org/10.3390/healthcare7040150

Hegedus, A., Trzaskoma, L., Soldos, P., Tuza, K., Katona, P., Greger, Z., Zsarnoczky-Dulhazi, F., & Kopper, B. (2020). Adaptation of fatigue affected changes in muscle EMG frequency characteristics for the determination of training load in physical therapy for cancer patients. *Pathology & Oncology Research*, *26*(2), 1129–1135. https://doi.org/10.1007/s12253-019-00668-3