Methods for step event detection via gastrocnemius medialis EMG and IMU

Aurora Rosato[1], Elena M. Gutierrez-Farewik [2], Seraina A. Dual[1]
[1] Department of Biomedical Engineering, KTH Royal Institute of Technology, Stockholm, Sweden
[2] KTH MoveAbility Lab, Dept. Engineering Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
Email: seraina@kth.se

Summary

The gastrocnemius (GAS) muscle plays several critical roles during gait, mechanically for support and propulsion gait and physiologically as a key component of the calf muscle pump. This study aims to evaluate methods for step detection and stride duration estimation during walking using electromyogram (EMG) and inertial measurement units (IMUs) placed on the GAS medialis. We suggest that stride duration can be reliably computed from the maximum shank acceleration, as it demonstrated consistent timing in all subjects.

Introduction

An activated GAS muscle plays a critical role as part of the calf muscle pump in returning venous deoxygenated blood to the heart. Correctly timing stepping and GAS activation with cardiac contraction has shown to significantly impact hemodynamics [1]. Characterizing GAS activation during gait with minimal instrumentation can provide valuable insights into calf muscle pump efficacy. While GAS muscle activation during gait is well-studied, whether wearable sensors can serve a dual function to detect gait events remains unexplored, specifically EMG sensors equipped with IMUs. Acceleration magnitude is easy to measure and not overly sensitive to sensor positioning. This study evaluates two methods for identification of stride duration and gait events using EMGs and IMUs placed on the GAS medialis in comparison to a chest-mounted IMU.

Methods

In this study, 22 subjects (55.8 ± 22 years old) were included. Three EMG+IMU sensors (Cometa, sampling frequency 2kHz) were placed on the chest and the GAS medialis of both legs. Subjects walked for 15 minutes on a treadmill at a constant comfortable speed. 29146 steps were analyzed in total. Stride duration was estimated from consecutive events, detected from 3 different outputs of the 3 wearable sensors. Events were detected as:

- G-crossing (t_g): chest vertical acceleration = 9.81 m/s^2, as previously used as indicator of heel strike [1].
- Shank acceleration (t_s): peak acceleration magnitude of shank segment (4th order Butterworth high pass filter 30 Hz).
- EMG-on (t_{emg}): GAS EMG reaches threshold of 20% max RMS EMG, a 125 ms window (4th order Butterworth band pass 20–450 Hz)

Durations deviating by more than ±1 standard deviation from the mean of the previous 20 values were identified as outliers and replaced with the mean value. Each gait cycle was defined as consecutive t_g events. The average relative timing of t_s and t_{emg} in the gait cycle was computed. Pair-wise agreement between stride durations from t_s and t_{emg} vs. t_g events was calculated with Bland Altman with a 95% confidence interval (CI).

Results and Discussion

The t_s and t_{emg} events occured at different timings in the gait cycle, but cosistently among subjects; t_s occurred at 22.6±11.5% gait cycle, and t_{emg} occurred at 55.1±14.3% gait cycle (Figure 1). Stride duration showed good agreement between all methods of event detection (Figure 2). Durations between t_s events (-0.01 [-0.07 0.04] s, t_g - t_s) had lower variation and agreed better with t_g events than durations between t_{emg} events (-0.01 [-0.08 0.06] s, t_g – t_{emg}). In four subjects, signal artifacts resulted in durations outside of the 95% CI.

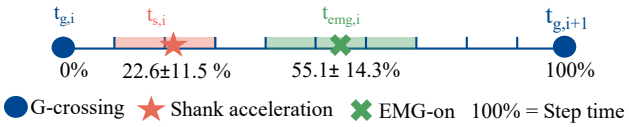

Figure 1: Sequence of events, as mean±STD, across all subjects.

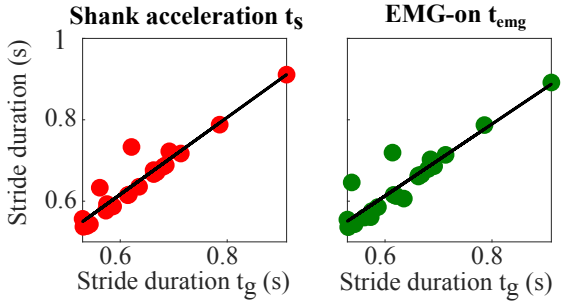

Figure 2: Side duration from shank acceleration (left) and EMG-on (right) vs. G-crossing stride duration, one point per subject.

Conclusions

For gait experiments with only a few EMG and/or IMU sensors, we suggest that stride duration can be reliably computed as the duration between consecutive instances of maximum shank acceleration, as measured by an IMU-equipped EMG sensor on the medial GAS. Future work can confirm this finding with instrumented motion capture. GAS-based detection of stride duration together with electrocardiogram for cardiac activation may simplify studies aimed to optimize calf muscle pump performance.

Acknowledgments

We acknowledge support from Promobilia Foundation and Åke Wiberg Foundation.

References

[1] K. Constantini, et. al, (2018), MSSE,**50**, 1046–105