Parametric Analysis of Fatigue in Stationary Biking: A Computational Approach

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Introduction

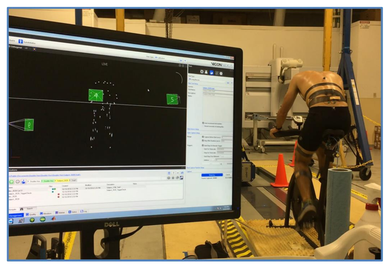
- As personal fitness is increasingly prevalent in society, a focus on maintaining safe exercise technique is crucial in avoiding training injury.
- Stationary biking, or spinning, is an exercise commonly done in large group settings led by an instructor who controls cycling intensity, but does not closely monitor individual technique.
- Over long duration training, fatigue may cause improper cycling form, leading to knee, hip, and back injuries. Performance fatigue research is also applicable to the military, athletics, and clinical rehabilitation

Objectives

1. Develop streamlined protocol for long duration volunteer testing.
2. Establish analysis pipeline for post processing of kinematic, kinetic, and physiological data.
3. Conduct multi-variate investigation of fatigue-induced performance changes.
4. Identify volunteer parameters potentially linked to the fatigue process.

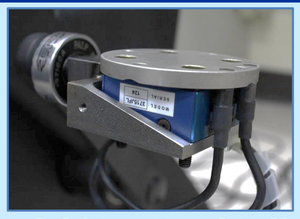
Methods

Data Collection

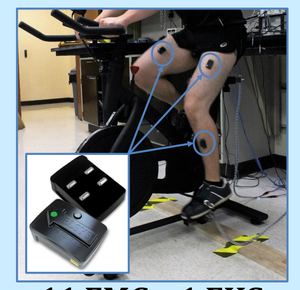


Data Collection Methods

Motion Capture System
65 Markers, 9 Cameras

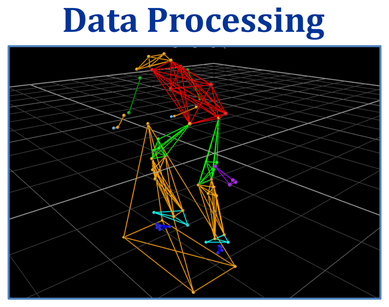


Pedal/Seat Load Cells
& Velocity Gate

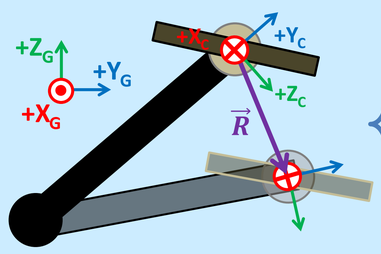


11 EMGs, 1 EKG

Data Processing



Power Calculation



$$P_{avg} = \frac{Work}{Time} = \frac{Force * Distance}{Time}$$

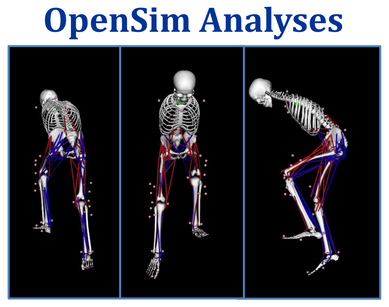
Assuming Work to Rotate Pedal ≈ 0,

$$P_{avg}(t) = \frac{\frac{1}{2}[F_{Cz}(t-1) + F_{Cz}(t)] * \|\vec{R}\|}{\Delta t}$$

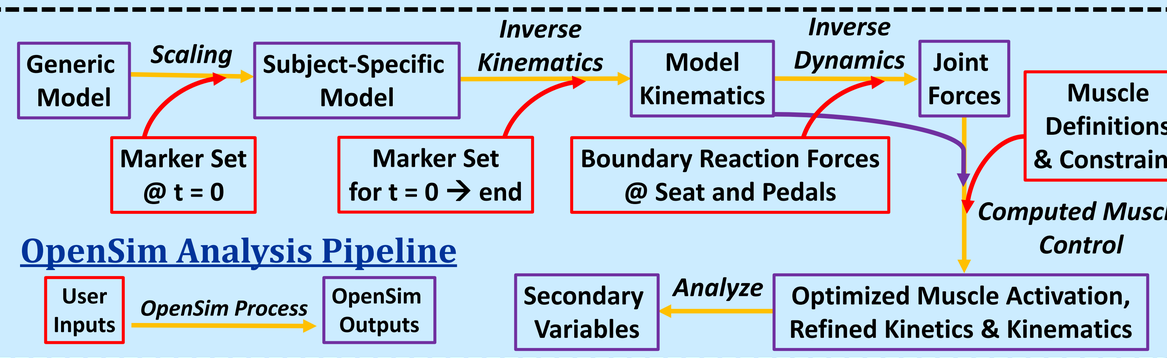
EMG Filtering

60 Hz 4º Notch
↓
30-300Hz 4º BPF
↓
De-Mean
↓
Rectify
↓
20Hz 4º LPF

OpenSim Analyses



OpenSim Analysis Pipeline

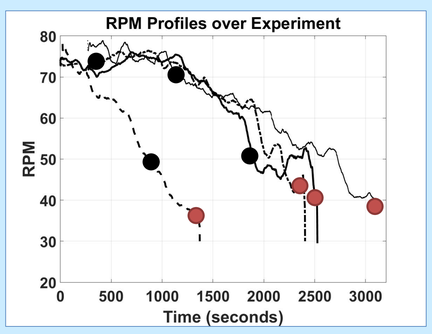


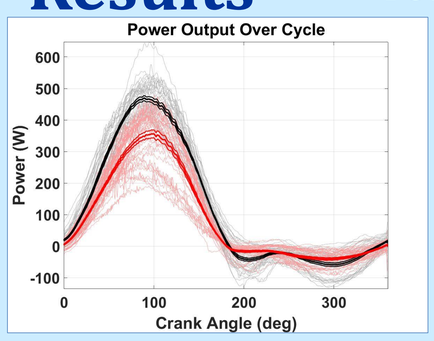
Results

Kinetics

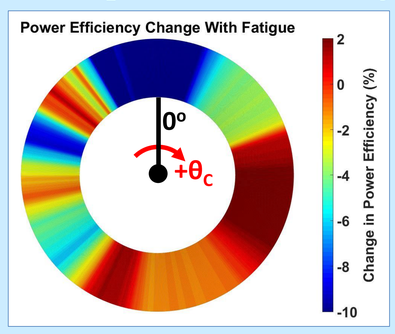
Guided and Resultant RPM Profiles

Guided Endurance Routine		
Duration	*Resistance*	*Target RPM*
2.5 minutes	Low	60-75
2.5 minutes	Medium	60-75
2.5 minutes	High	60-75
Maintain**	High	60-75





Power Output and Efficiency Calculation

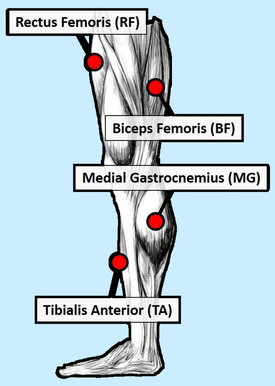


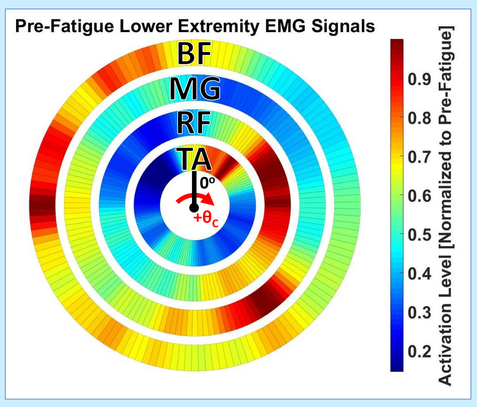
$$P_{efficiency} = \frac{P_{delivered\ to\ bike}}{\|P_{generated\ by\ rider}\|}$$

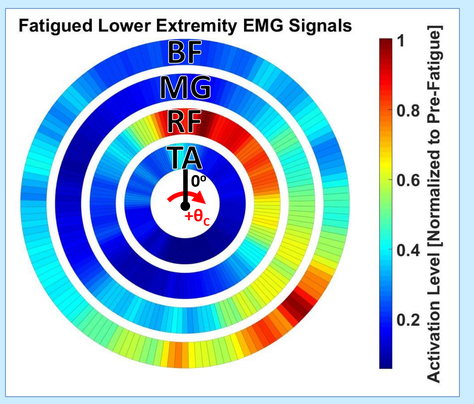
$$P_{eff}(t) = \frac{F_{Cz}(t)}{\sqrt{F_{Cx}(t)^2 + F_{Cy}(t)^2 + F_{Cz}(t)^2}}$$

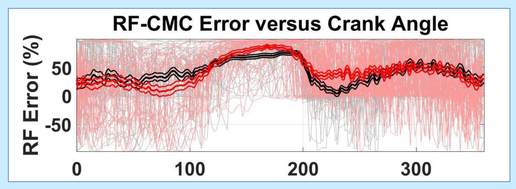
Physiology

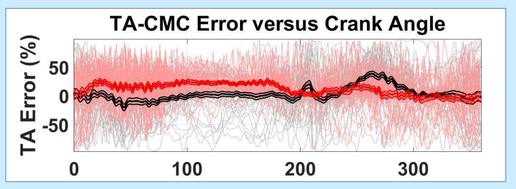
Muscles of Interest

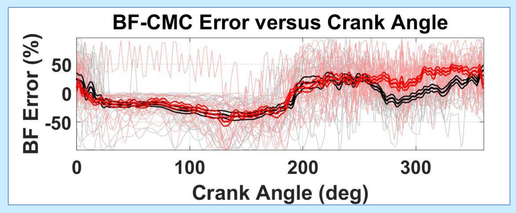


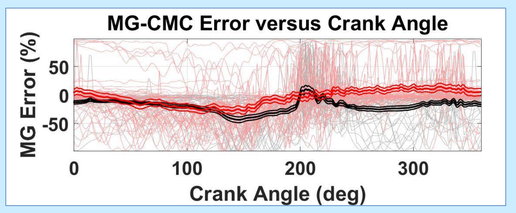






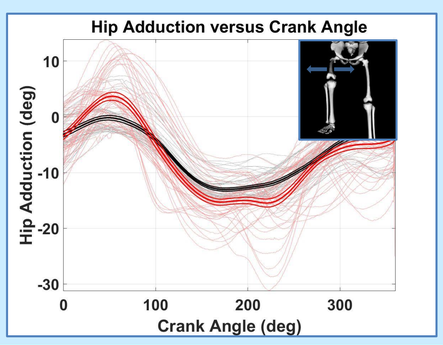


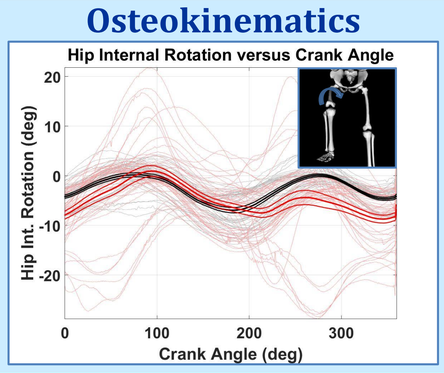


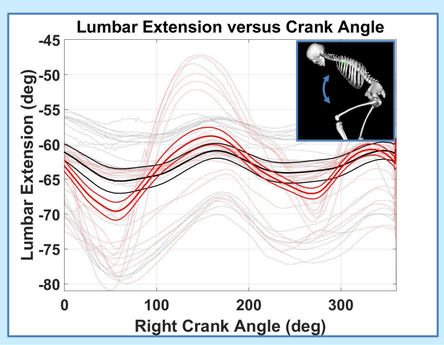


Kinematics

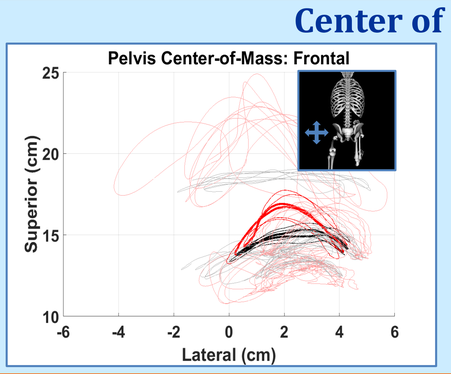
Osteokinematics

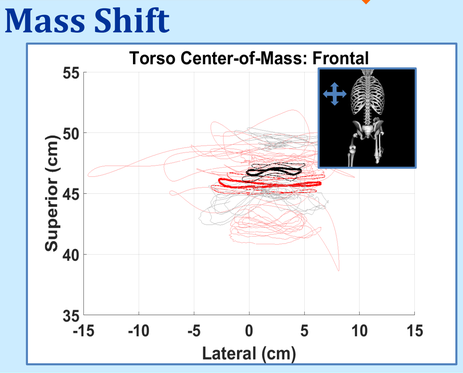






Center of Mass Shift





Discussion

- Four of the thirteen subjects exhibited uniform fatigue during their test, characterized by: decreased net power output, increased kinetic variability, and slightly decreased power efficiency.
- Physiological changes were seen bilaterally in parallel with kinetic performance reduction, such as: loss of tibialis anterior activation on the down stroke, duration decrease and amplitude increase of the rectus/biceps femoris.
- Computational prediction of muscle activation shows large deviations from experimentally observed muscle activation patterns. Such incongruences of the data could be attributed to the noise associated with EMGs or error propagations commonly seen in computational modeling.
- Osteokinematic variability in the hips and lower back indicate increased mediolateral knee sway, hip external rotation, and lumbar flexion. Center of mass tracking of the pelvis demonstrates anterior excursion, while the torso indicates increased lateral sway. Further statistical analyses are necessary for fatigue model development.

Acknowledgements

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References

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