Parametric Analysis of Fatigue in Stationary Biking: A Computational Approach

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As personal fitness becomes increasingly prevalent in society, a focus on maintaining safe exercise technique is crucial to avoid unintended training injury. Stationary biking, or spinning, is an intense cardiovascular exercise that is commonly done in large group settings led by an instructor who controls the intensity of the sessions, but does not closely monitor individual technique. Over the duration of a spinning session, individual technique will often adapt as fatigue sets in, and this can lead to improper cycling form and training injuries to the knee, hip, and back. The goal of this research is to understand the relationship between performance, technique, and muscle fatigue during a spinning session by combining kinematic, kinetic, and physiological data in a computational model framework.

Thirteen volunteers were guided through a stationary bike endurance routine performed at the University of Virginia’s Center for Applied Biomechanics. Prior to testing, volunteers were fitted with 46 retroreflective motion-capture markers (Vicon) and 11 wireless EMG sensors (Delsys) to track body kinematics and muscle electrical signals, respectively. The stationary bike was instrumented with 6-axis load cells in the pedals and seat. Following a pre-test stretching and warm-up phase, the volunteers were put through a calibration phase where they were asked to maintain a 60-75 RPM cycle pace with minimal pedal resistance. Pedal resistance was incremented through “low”, “medium”, and “high” resistance levels (self-reported), reflecting conditions of a steep climb uphill. Once at “high” resistance, participants were asked to maintain a target pace of 60-75 RPM without dropping below 30 RPM. Data collection stopped when the volunteer fatigued to a pace below 30 RPM, or when the total ride time reached 67.5 minutes. For this abstract, we are presenting data collected and post-processed from one subject.

Using OpenSim, volunteer data was integrated for kinematics and joint kinetics, muscle activation level and timing profiles. Early in the test, when the pedal resistance incremented from medium and high resistance, the volunteer increased peak power output by 185W to maintain pace, but efficiency and osteokinematics in the lower extremities and core were unaffected. During this transition, the bilateral tibialis anterior activation increased and exhibited a bimodal activation profile during pre-down stroke and early-upstroke of the cycle. While the subject fatigued and cadence dropped to 30 RPM, power output decreased substantially (Figure 1, left) and cycling technique was adjusted. Lumbar flexion increased (Figure 1, right) resulting in an increase in hip adduction range of motion ($+4^{o}$), hip external rotation ($+4.5^{o}$), and anterior tilt of pelvis. Early-upstroke activation of the tibialis anterior ceased, inducing compensatory activation of the biceps femoris and medial gastrocnemius on the upstroke.

The analysis identified fatigue-induced performance changes, providing a foundation for a performance-fatigue model that can be developed to understand degradation of technique and elevated injury risk associated with fatigue. Future work in this area may have profound implications in clinical rehabilitation, athletic training, and military applications.

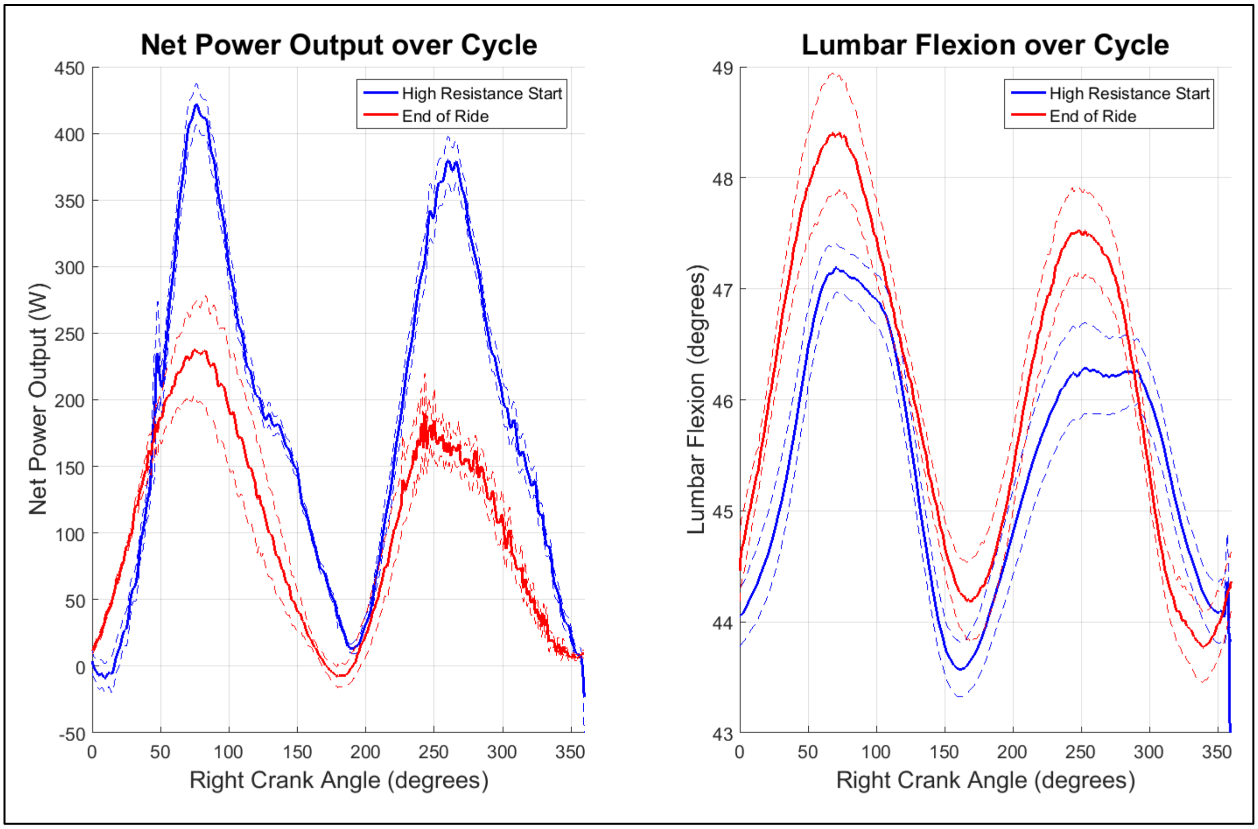

Figure 1: Net power output (left) and lumbar flexion (right) during two fatigue states from a single volunteer over a full cycle. Solid line = mean (n = 5 cycles). Dashed line = ±1 standard error.