TRACKING KINEMATIC CHANGES IN ELITE CYCLISTS DURING FATIGUE

Jason E. Joubert and Jonathan B. Dingwell

Nonlinear Biodynamics Lab, Dept. of Kinesiology, University of TX, Austin, TX, USA
E-mail: jdingwell@mail.utexas.edu Web: http://www.edb.utexas.edu/faculty/dingwell/

INTRODUCTION

Recent popularization has drawn more people into recreational and competitive cycling. This has lead to an increase in cycling injuries that may be due to biomechanical inefficiencies (Asplund 2004). At 85 rpm, a cyclist performs over 5000 revolutions every hour. As fatigue sets in, changes in muscle activation patterns may *cause* changes in kinematics. Alternatively, these changes may reflect a strategy used to maintain performance while trying to *minimize* fatigue. In both cases, non-optimal kinematics could cause joint mal-alignments that have a large cumulative effect over frequent long rides.

Typical “pre. vs. post” experimental designs assume one kinematic strategy exists prior to fatigue and a second exists following fatigue. Such experiments cannot quantify changes in kinematics *across* the experiment. In an upper extremity repetitive lifting task, untrained subjects exhibited continuous changes in coordination over time that varied greatly both within and between subjects (Voge 2004). These variations suggest subjects tried a wide variety of strategies to combat progressing muscle fatigue. However, they may instead have been due to either the unconstrained nature of the task, the untrained nature of the subjects, or both.

The present study tested elite cyclists cycling on a stationary bicycle. We tested the hypothesis that even highly trained elite athletes performing a more kinematically constrained task would also exhibit varying and non-monotonic changes in movement kinematics in response to fatigue onset.

METHODS

Ten elite (USCF Category 3 or higher level of competition) male cyclists, age 18 – 45 yrs, participated. Each subject was marked with reflective markers (Fig. 1) to collect sagittal plane kinematic data. Participants cycled to exhaustion on a Lode Excalibur Sport bicycle ergometer at a pre-calculated work load equivalent to 100% of their VO_2max. Subjects were given vigorous verbal encouragement throughout the trials, which lasted 4 – 10 min. Kinematic data were sampled at 120 Hz continuously throughout each trial using a Vicon Motion Analysis system (Oxford Metrics, Oxford, UK). The variations exhibited in different joint angles (Fig. 1) were examined *within* subjects to assess nonstationarities that occurred as fatigue progressed and *across* subjects to determine what kinematic changes were common among elite cyclists.

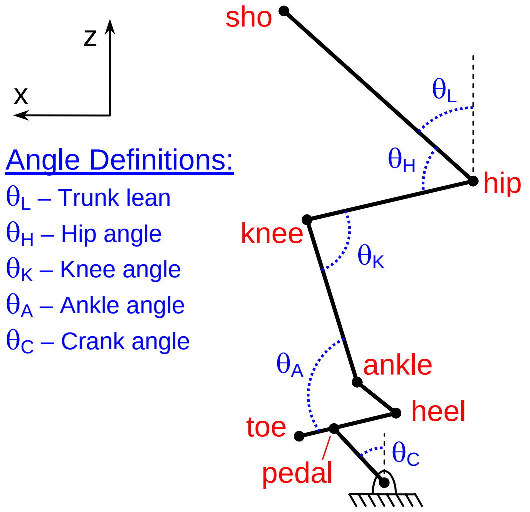

Figure 1: Left sagittal plane view of the cyclist showing locations of reflective markers and definitions of joint angles computed.

RESULTS AND DISCUSSION

All joint angles in all subjects exhibited non-monotonic and non-stationary behaviors in response to the fatigue protocol. Different joint angles exhibited different *types* of non-stationarities. While there were differences *between* subjects, several trends *across* subjects were evident. For example, all subjects increased their trunk flexion as time progressed (Fig. 2). This likely reflected a strategy to increase the stretch response of the hip extensors to maintain total power output. However, at various times in the fatigue protocol, different subjects made noticeable shifts in trunk flexion and shortly after returned towards the trend line.

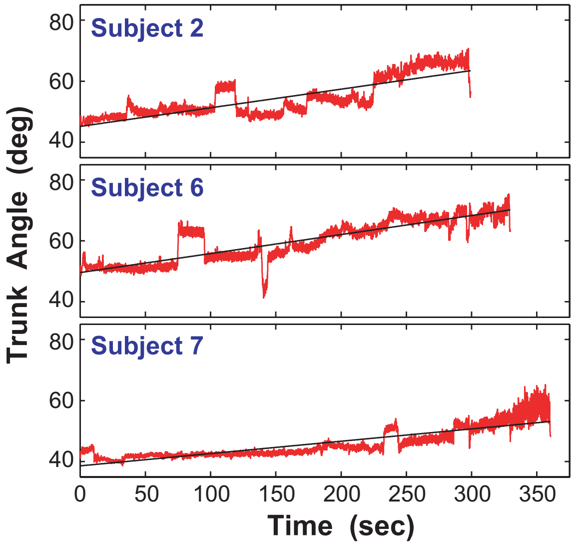

Figure 2: Changes in trunk flexion angles (θ_L; in red) over the entire trial for 3 representative subjects. Linear regression lines (in black) show positive trends.

All subjects generally showed a smooth decreasing trend in ankle angle (θ_A) as time progressed (Fig. 3). However, there were also changes in the *range* of ankle motion *within* each subject that differed in direction *between* subjects. For example, Subject 2 tended to use *less* ankle range of motion, whereas Subject 6 tended to use *more* range of motion as fatigue progressed (Fig. 3).

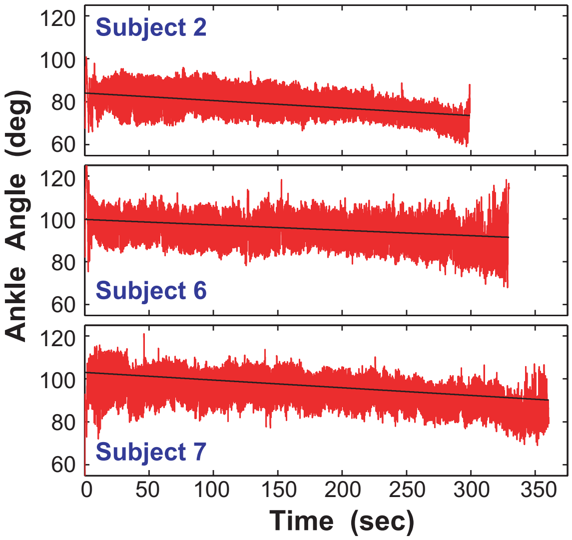

Figure 3: Changes in ankle angles (θ_A; in red) over the entire trial for 3 representative subjects. Linear regression lines (in black) show negative trends.

SUMMARY/CONCLUSIONS

As hypothesized, elite cyclists changed their kinematics in non-monotonic ways. While there were differences across joint angles and across individuals for each angle, those changes were generally consistent with the idea that subjects were trying to prevent the progression of muscle fatigue. These findings extend the work of Voge (2004) by demonstrating that even highly trained elite athletes executing a far more kinematically constrained task still exhibit multiple and continuous changes in their kinematics to maintain power output while delaying the effects of fatigue for as long as possible.

REFERENCES

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