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Muscular fatigue of the lower limb and subsequent joint angle adaptations during a 16.1km cycling time trial

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Abstract

Background: Effective muscular recruitment during cycling is crucial to optimising performance. As such, much research has examined when muscles are active during the pedal revolution and how muscle co-activation may influence pedalling technique but little evidence associated with the effect of fatigue on lower limb joint angles and its subsequent effect on power output and muscle recruitment. Purpose: Are changes in muscular recruitment patterns and changes in lower limb kinematics detrimental to performance?

Methods: A preliminary case study of a well-trained veteran cyclist ($\dot{V}O2$peak 49.9 ml . kg-1 . min-1 and PPO of 400W) conducted a 16.1km simulated cycling time trial on a Wattbike Pro at 80% PPO with a cadence of 98 rpm. Bilateral surface EMG were employed using pairs of Ag/AgCl electrodes adhered to both right and left vastus medialis (VM), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius (GM). Intervals of sixty seconds in duration, of 3D kinematic and electromyography (EMG) data were synchronised using a Vicon motion capture system throughout the time trial. Ten consecutive pedal revolutions per 60 s interval were processed for subsequent analysis. Kinematic and EMG data signals were imported into Visual 3D v.5 and Matlab for processing.

Results: There were statistically significant changes ($p<0.05$) in all kinematic data across nine time points. Fundamental changes occurred between minute 10-12 with a decrease in flexion angle for the left hip ($z = -9.56$, $p<0.05$, $r = 0.55$), and the right hip, ($z = -7.67$, $p<0.05$, $r = 0.44$). The left ankle starts to have a greater planter flexion ($z = -9.69$, $p<0.05$, $r = 0.56$) between minutes 10-12 and this continues to have a significant change between time points for the remainder of the trial. The magnitude of EMG data revealed that there were statistically significant changes ($p<0.05$) in all muscles across seven time points. Decreases in the magnitude of activation were observed between minutes 8-10 for both the left ($z = -9.17$, $p<0.05$, $r = 0.53$) and right ($z = -8.21$, $p<0.0005$, $r = 0.48$) TA. The frequency domain EMG analysis indicated a trend towards lower frequencies being recorded for the left and right TA and GM with a trend towards higher frequencies being recorded for the left and right VM. Analysis of the Wattbike data indicated that there were statistically significant differences from minutes 1 to 20 between left and right angle to peak force applied to the crank ($t(19) = 20.89$, $p<0.05$) with no statistical significance between left and right limb percentage use (95% CI 2.81, 3.31%). Indications showed that there was a higher magnitude of activation for the left leg across all muscles tested and the Wattbike data indicates greater power generation on the left side of the pedal revolution.

Discussion: Based on the results from this study there were decreases in the ankles range of motion (ROM) with increases in hip flexion from minute 10-12 with changes in neuromuscular activity between minutes 8-10 then there were smaller effect changes for the remainder of the time trial. The alterations in the EMG median frequency indicated a trend towards muscular fatigue for TA and GM with increases in neuromuscular activity in both VM's possibly counteracting fatigue. The ankle's decrease in ROM may be a product of fatigue associated with the TA and GM but by becoming stiffer it may optimise the foot/pedal interface. Even with these changes in kinematic and EMG data the power output remained constant.

Conclusion: As this was a case study further work in this area needs to be considered in establishing variability in joint angles and how they may be beneficial/detrimental in generating the same level of power output when fatigued. An association of muscular fatigue in cycling and changes to lower limb joint angle variability requires further investigation examining joint coupling patterns, independent pedal power analysis and cross reference to physiological parameters for fatigue to establish strategies that may be beneficial in improving cycling performance.

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