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EFFECTS OF TWO DIFFERENT CADENCES IN MUSCLE COACTIVATION OF COMPETITIVE CYCLISTS

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SUMMARY
The aim of this study was to compare the effects of two different cadences at a constant workload on muscle activity and muscle coactivation of competitive cyclists. Two cadences were tested (70 and 90 rpm) at a constant power output related to the second ventilatory threshold (325 ±35W). Activation of tibialis anterior (TA), medial head of gastrocnemius (GM), soleus (Sol), long head of biceps femoris (BF) and vastus medialis (VM) muscles were assessed during the propulsion phase of crank cycle (0-180° of crank cycle) using surface electromyography. Superimposed timing was used to compute coactivation between antagonist muscles. Lower coactivation at 90 rpm compared to 70 rpm ($p<0.01$) was observed for BF/VM. Cyclists should use cadences close to 90 rpm to reduce muscle coactivation and improve their pedalling technique and cycling economy.

Keywords
EMG, cadence, coactivation, cyclists.

INTRODUCTION
In cycling, hip, knee and ankle joint net moments are affected by coactivation of single and multi-joint muscles [1]. Coactivation of antagonist muscles to a given joint motion has been linked to reduced efficiency in muscle force production with potential reductions in net torque [1]. Excessive coactivation could be translated into less developed technique [2] and to greater energy cost during cycling. Cyclists presented less coactivation for the knee joint flexors (i.e. biceps femoris) to knee joint extensors (i.e. vastus lateralis and rectus femoris) than triathletes for varying pedaling cadences (60, 75, 90 e 105 rpm) [3]. Indeed, Lucia et al. [4] showed that professional cyclists have greater economy and lower muscle activation at faster cadences (100 rpm) than at slower cadences (60 rpm). However, to date, there were no studies assessing coactivation of knee and ankle joint muscles of competitive cyclists. Therefore, this study compared the effects of two pedaling cadences (70 and 90 rpm) in knee and ankle joint muscles coactivation.

METHODS
Twelve cyclists (age: 28 ±6.6 years; body mass 71 ±6.8 kg; height 177 ±9.7 kg; maximal power output - PO_{Max} 375 ±30.1 W; power output at the second ventilatory threshold – PO_{VT2} 315 ±49.4 W) participated in the study, which was approved by the University's Ethics Committee in Human Research.

Protocol
On the first session, anthropometric measurements (height and body mass) were obtained. Participants warmed up at 150 W for 10 minutes before the test began using their own bicycles mounted on a stationary cycling trainer (Computrainer, ProLab 3D, USA) to determine maximal power (PO_{MAX}) and power output at the second ventilatory threshold (PO_{LV2}). The protocol consisted of a step test with increments of 25 W every minute until exhaustion. Pedalling cadence was visually controlled close to 90 ±2 rpm. After 48 hrs, they returned to the laboratory where they warmed up at 150 W for 10 minutes. After that, they rode for two minutes at the maximal power output taken in the first session using a pedalling cadence of 90 rpm (i.e. PO_{MAX}). The power output corresponding to the second ventilatory threshold (PO_{LV2}) was then used at each of the following conditions:

1. A cadence of 70 ±2 rpm
2. A cadence of 90 ±2 rpm

Each trial was separated by two minutes of rest on the bicycle and data was collected during the last 20 s for each trial. The order of pedalling cadences was randomized between cyclists.

Data collection
Muscle activities were recorded using surface electromyography for the right tibialis anterior (TA), the medial head of gastrocnemius (GM), soleus (SOL), the long head of biceps femoris (BF), rectus femoris (RF), and the vastus medialis (VM) muscles using a Bortec electromyography system (AMT-8, Bortec Electronics Inc., Calgary, Canada). Pairs of Ag/AgCl electrodes (bipolar configuration) with a diameter of 22 mm were positioned on the skin after carefully shaving and cleaning the area using an abrasive cleaner and alcohol swabs to reduce the skin impedance as recommended by the International Society of Electrophysiology and Kinesiology [5, 6]. The electrodes were placed over the belly of the muscles, one third of the muscle length from the midpoint (to avoid the musculotendinous junction), parallel with the muscle fibers and taped to the skin using micropore tape (3M Company, USA). The reference electrode was placed over an

electrically neutral bony prominence (anterior surface of the tibia). The electrodes' wires were then taped to the skin to reduce movement artefact. EMG was recorded at 2100 Hz using a 16-bit analogical to digital converter (DI720, DataQ Instruments Inc., USA) using WINDAQ® software (WINDAQ, DataQ Instruments Inc., USA). A reed switch attached to the bicycle frame generated a pulse that was collected along with EMG signals by the analogical to digital converter and used to separate signals for each crank cycle.

Data analyses

The raw EMG signals were filtered using a band-pass Butterworth filter with cut-off frequencies optimized to reduce signal residuals [7] and normalized by the activation recorded at the maximal power output trial performed in the second session (i.e. PO_{MAX}). Signals were cut and averaged for ten consecutive crank revolutions for every muscle of every participant. The RMS envelopes were computed and a threshold of 10% of the maximal activation was defined to detect onsets and offsets of muscle activation (timing) [8]. Superimposed timing (coactivation) was calculated for biceps femoris and rectus femoris (BF/RF), biceps femoris and vastus medialis (BF/VM), tibialis anterior and gastrocnemius medialis (TA/GM) and for tibialis anterior and soleus (TA/Sol). EMG data analysis was conducted using custom written scripts in MATLAB®. T-tests ($\alpha<0.05$) and effect sizes ($d>0.80$) were used to detect significant differences in coactivation from changes in pedalling cadence (70 vs. 90 rpm).

RESULTS AND DISCUSSION

A reduction in coactivation for BF/VM at 90 rpm ($p<0.01$ and $d = 0.95$) may have been linked to a reduced timing for BF or an increased timing of VM. This finding is different from the unchanged coactivation observed in varying pedaling cadences on a previous study [3]. However, in line with findings from Lucia et al. [4], reduced coactivation for knee extensors observed in our study may reflect less resistive force from knee flexors to the knee extensor moment required to drive forces to the pedals during crank cycle. That would potentially increase cycling efficiency and performance when pedaling at 90 rpm compared to 70 rpm. Hautier et al. [9] showed that after fatigue from maximal sprints, cyclists reduce BF/VM coactivation to optimize net knee joint moment. Therefore, reducing knee flexors to extensors coactivation by opting for higher pedaling cadences could improve knee joint net moment and power production.

CONCLUSIONS

Competitive cyclists showed less coactivation for BF/VM at a higher cadence compared to a lower cadence. Cyclists should use higher cadences to improve pedalling technique and cycling economy.

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Table 1. Mean ± SD of coactivation for biceps femoris and rectus femoris (BF/RF), biceps femoris and vastus medialis (BF/VM), tibialis anterior and gastrocnemius medialis (TA/GM) and for tibialis anterior and soleus (TA/Sol). N = 12.

	TA/GM	**BF/RF**	**BF/VM**	**TA/SOL**
70 rpm	71.1 ±25.9	65.7 ±22.5	64.9 ±8.3	72.7 ±26.2
90 rpm	79.2 ±21.5	61.6 ±24.0	56.7 ±8.9*	74.0 ±29.5
70 vs. 90rpm				
%differences	10%	7%	14%	2%
p-value	0.11	0.01	<0.01	0.80
effect size	0.34	0.18	0.95	0.05

* significant differences ($p<0.05$ and $d>0.80$) between cadences.