

Conference Abstract

Influence of Cadence and Road Gradient on Metabolic and Biomechanical Parameters during Submaximal Cycling: a Pilot 2×2 Factorial Study

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1. Introduction

In cycling, a single power output can be achieved at various combinations of cadence and force; nevertheless, consensus is lacking regarding criteria for selecting the optimal cadence. Several studies reported differences in metabolic (oxygen uptake, lactate, ventilation) and neuromuscular parameters at different pedaling rates (Ahlquist et al., 1992; Lucia et al., 2001). More recently, it has also been observed that the work rates at which respiratory compensation point (RCP) and critical power (CP) occur were influenced by pedaling cadence (Broxterman et al., 2015). Furthermore, other studies indicated that joint contributions are affected by cadence, suggesting that differences in biomechanical parameters could also play a role (Skovereng et al., 2016).

Another factor that affects cadence is road gradient. However, research on how road gradient influences metabolic and biomechanical responses is limited, partly due to the difficulty of obtaining data, both in laboratory and outdoor conditions. To our knowledge, the only study that combined in a comparable way cadence and gradient was that conducted by Bertucci and colleagues (2005), which conducted two tests on level

ground (flat road) at 80 and 100 rpm, and two tests on a 9.25% uphill (outdoor), at 60 and 80 rpm. The outcome variable was the crank-torque profile, and the main finding was that the crank-torque profile varied substantially according to cadence and in minor part due to the gradient.

This pilot 2×2 factorial study explored the effects of pedaling cadence and road gradient on cyclists' cardiorespiratory and biomechanical parameters during submaximal cycling. We expected to confirm the literature regarding the metabolic and biomechanical differences between (a) low and high cadences, and (b) flat and uphill positions, and we also hypothesized that the road gradient would enhance the cadence-related differences.

2. Materials and Methods

2.1. Subjects

Four male trained/highly trained cyclists (32.8 ± 4.3 years old) participated in the study.

2.2. Design

A factorial 2 × 2 design (two cadences × two gradients) was used. Participants visited the laboratory on two occasions: the first



time, a ramp incremental exercise test was performed to determine power at first (W_{GET}) and second thresholds (W_{RCP}), while on the second visit, participants underwent the experimental protocol, which consisted in 4×5 -min bouts at $100\% W_{RCP}$, with 10-min active recovery ($90\% W_{GET}$) in between, one trial for each of the four conditions: flat low cadence (0%, 55-60 rpm), flat high cadence (0%, 90-95 rpm), uphill low cadence (6.5%, 55-60 rpm), uphill high cadence (6.5%, 90-95 rpm).

2.3. Methodology

Power, torque, cadence, heart rate, ventilatory (oxygen uptake, ventilation), and biomechanical (kinematics) variables were continuously recorded during the experimental sessions. Power and torque data were recorded second-by-second using SRM pedals (SRM Italia Srl, Italy) to use the same power meter for all participants. The participants' bike was mounted on a Wahoo Kickr ergometer, connected to the Zwift software (Zwift Inc., US), which regulated the ergometer resistance through the ERG mode; the road gradient was adjusted using a Wahoo Kickr-Climb (Wahoo Fitness, US).

2.4. Statistical Analysis

For exploratory purposes, a linear mixed model analysis was conducted to compare conditions (high vs low cadence; flat vs uphill), in which model gradient and cadence were used as fixed effects, while ID as a random effect to account for the repeated measures of the data. The analyses were conducted using Python and RStudio, at a standard significance level of $\alpha = 0.05$.

3. Results

Significant differences were found between high and low cadence (fixed-effect cadence) for torque ($p < 0.001$), VO_{2peak} ($p = 0.002$), and VE ($p = 0.008$) (Figure 1). No significant differences were reported between flat and uphill conditions.

The analysis of the crank-torque profile showed that the angle at which peak torque (T_{peak}) is expressed varies between conditions (Figure 2). A significant effect on the angle at T_{peak} was reported both for gradient ($p = 0.022$) and cadence ($p < 0.001$).

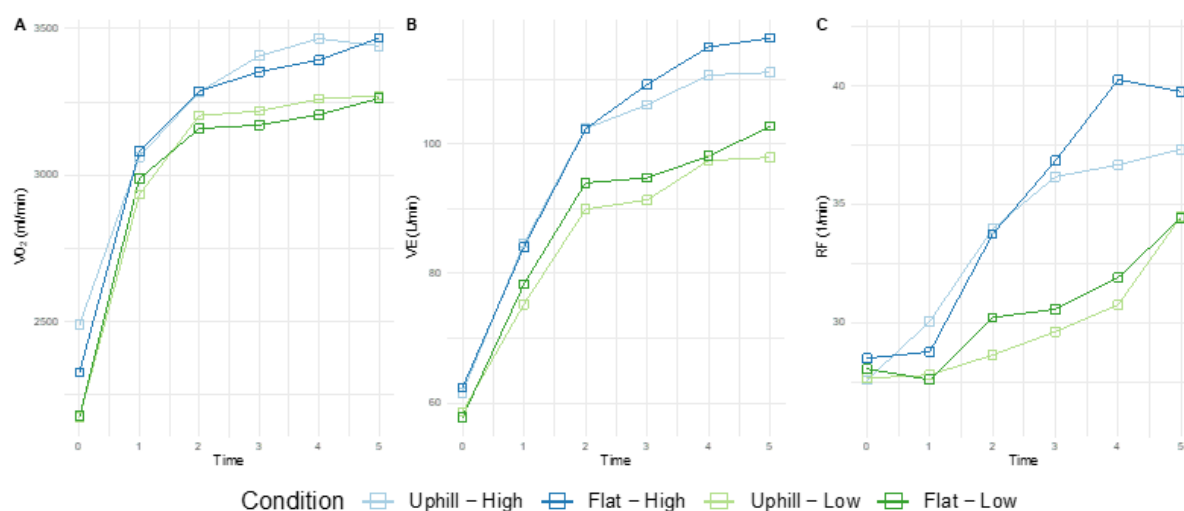


Figure 1. Trends of VO_2 , ventilation and respiratory frequency as a function of time in the four experimental conditions.

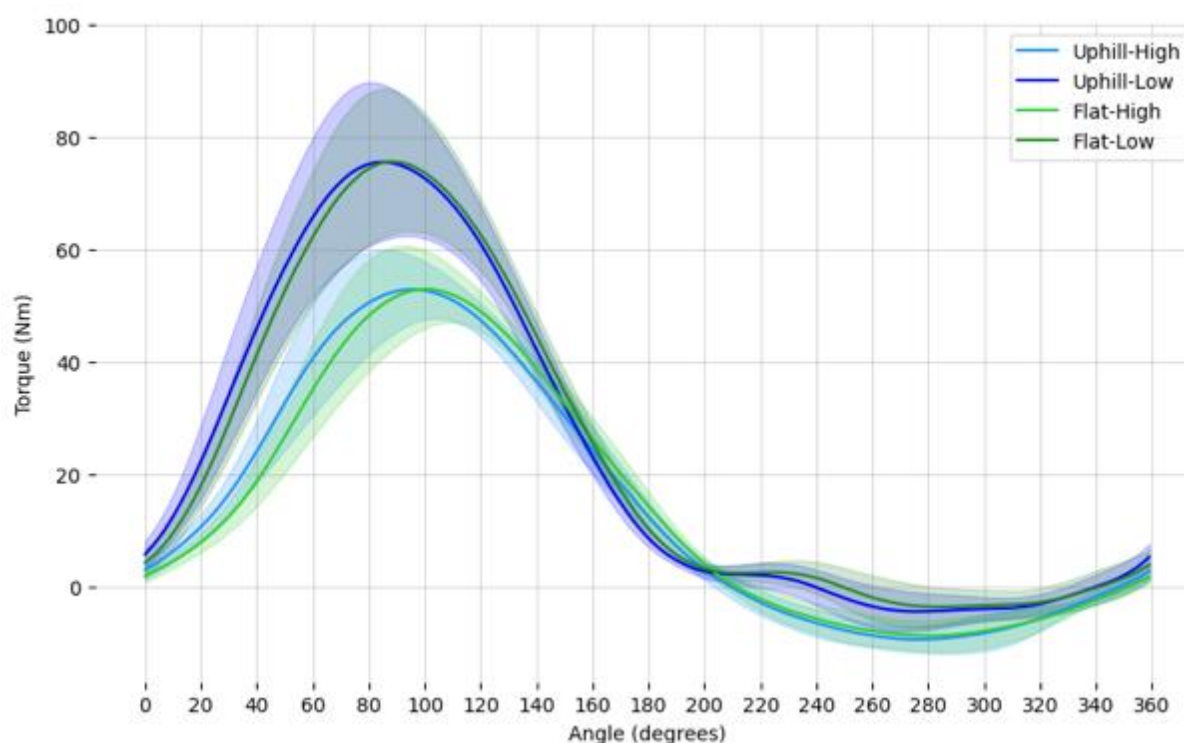


Figure 2. Crank-torque profile as a function of pedal cycle in the four conditions.

4. Discussion

To our knowledge, this is the first study that investigated the interaction between cadence and gradient, under controlled laboratory conditions, and that integrated both metabolic and biomechanical measurements. The main findings of our research only partially confirm the original hypothesis: indeed, if our results confirmed an effect of pedal cadence on cardiorespiratory and metabolic responses, we failed to find any difference enhancement related to the road gradient. We found that metabolic responses (VO_2 and VE) were higher in the high cadence condition, independently of road gradient, in accordance with previous studies (Boone et al., 2015; Broxterman et al., 2015). Moreover, we reported that both cadence and road gradient were associated with a different angle at T_{peak} in the crank-torque profile. These results are in accordance with Bertucci et al. (2005), which suggested that, as in each condition the muscles operate across different portions of their active force-length relationship and at different contraction velocities, in order to optimize cycling performance should be important to train in

specific conditions (uphill road cycling and level ground, low and high cadences) for stimulating specific muscular adaptations. This can be highlighted as an important limiting point of the literature about low cadence / high torque training in cycling.

5. Practical Applications

Although the VO_2 associated with RCP does not appear to be different between low and high cadences, the work rate associated with this (and other) intensity boundary differs, and this posits a question of whether training zones, commonly used to prescribe training programs, should be adapted or not to different cadences. For example, when performing low cadence / high torque intervals, if the power output associated with a given intensity (for example, CP) is greater when riding at low cadence, should the power target be set higher accordingly? Future studies are needed to better understand the determinants of optimal cadence during cycling and optimize training programs using the combination of different gradients and cadences to stimulate specific muscular adaptations.

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Conflicts of Interest: The authors declare no conflict of interest.

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