

How simulated lead-up exercise-induced fatigue affects the sprint performance in elite road cyclists?

Evan Guenego ¹, Maxime Robin ¹ and Sylvain Dorel ^{2,*}

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¹ TotalEnergies Pro Cycling Team,
Essarts-en-Bocage, France

² Nantes Université, Motricité-
Interactions-Performance, MIP, UR
4334, Nantes, 44000, France

Correspondence

Sylvain Dorel

Nantes Université, Motricité-
Interactions-Performance, MIP, UR
4334, Nantes, 44000, France

sylvain.dorel@univ-nantes.fr

Abstract

This study aimed to characterize the effects of one-minute fatiguing exercise simulating the approach to a final sprint in road cycling on the capacity to produce maximal power output during that sprint. Twelve elite male cyclists participated in a single test session. First, cyclists performed a force-velocity (F-V) test on a cycle ergometer to determine their maximal force-velocity-power (F-V-P) profiles. Second, after one minute at $6.4 \pm 0.4 \text{ W} \cdot \text{kg}^{-1}$ with power variations simulating the approach to a final sprint in road cycling, they immediately performed a 5-s single sprint F-V test to assess the alteration of the F-V-P profile (POST-1MIN). Finally, they directly performed 15-s isokinetic sprint 82.5% of V_{opt} , immediately following by a 5-s single sprint F-V test to assess the final alteration of F-V-P profile (END). Results show that this one-minute exercise led to a significant reduction in maximal power ($-25 \pm 7\%$), maximal force ($-9 \pm 7\%$), and optimal pedaling rate ($-17 \pm 7\%$), with a more pronounced decrease in velocity capabilities for initiating the final sprint, highlighting a state of fatigue. Then, at the end of the final sprint, maximal power further decreased by $18 \pm 7\%$, with a “parallel” shift in the F-V profile. The mean power output during the final sprint was strongly associated with the P_{max} determined after the one-minute exercise. These results highlight that determining the F-V-P profile under fatigued conditions seems essential to better assess the sprint performance ability of riders in competition.

Keywords

force-velocity relationship; road cycling; fatigue; sprint performance; professional cyclists

1 Introduction

In road cycling, most races are decided during a final sprint, where riders produce maximal effort to outperform their competitors (Menaspà et al., 2015). Sprint performance is strongly associated with the ability to produce and maintain peak power outputs (Douglas et al., 2021). This maximal power production capacity ($P_{\max}$) is determined by the interaction both maximal force ($F_{\max}$) and maximal velocity ($V_{\max}$) components.

Prolonged maximal sprint induces rapid fatigue, leading to a decrease in $P_{\max}$ and an alteration in the force-velocity (F-V) profile, characterized by a decline in force and velocity capabilities (Buttelli et al., 1996; De Ruiter et al., 1999). In addition, in real racing conditions, sprints are performed following high-intensity efforts. It has been shown that fatigue accumulated prior to the sprint strongly influences performance (Menaspà et al., 2015; Robin et al., 2021). For example, Robin et al. (2021) reported that, the peak power produced during final sprints in competition, only reached $90.1 \pm 7.0\%$ of $P_{\max}$.

To our knowledge, only few studies have examined the effects of fatiguing exercise on force-velocity-power (F-V-P) relationships in cycling. Buttelli et al. (1997) examined the effects of an aerobic preload, but under conditions that differ significantly from those encountered in competition. Consequently, the impact a fatiguing exercise simulating the final approach to a sprint on the evolution of F-V-P profiles during sprinting remains unknown.

The aim of this study was to characterize the changes in maximal power ($P_{\max}$) and its both force and velocity components during a sprint performed following a one-minute fatiguing exercise. We hypothesized that the resulting fatigue plays a major role in sprint performance by altering both mechanical determinants of $P_{\max}$.

2 Material and Methods

2.1 Participants

Twelve elite male cyclists volunteered to participate in this study (height: 177.8 ± 4.3 cm; body mass: 69.9 ± 5.7 kg; age: 24 ± 4 years).

2.2 Experimental Design

This experimental study was conducted during a single session including multiple maximal sprints performed on an electronically braked ergometer (Excalibur Sport, Lode, The Netherlands), individually adjusted for each participant. After a standardized warm-up, participants completed three 3-4 seconds maximal sprints to establish maximal force-velocity (F-V) and power-velocity (P-V) relationships and the associated indexes ($P_{\max}$, $F_{\max}$, V_{opt}) (Dorel, 2018; Dorel et al., 2010).

Following a recovery period of 20-min, a one-minute high-intensity exercise was performed at an individualized intensity (130% of critical power, corresponding to 448.8 ± 24.2 W and 6.4 ± 0.4 W·kg⁻¹), immediately followed by a 5-s single sprint F-V test (Martin et al., 1997) to assess the alteration in F-V-P relationships after the one-minute fatiguing exercise ($P_{\max_POST-1MIN}$, $F_{\max_POST-1MIN}$, $V_{\text{opt_POST-1MIN}}$). Finally, they directly performed 15-s isokinetic sprint 82.5% of V_{opt} (accounting for the expected reduction in V_{opt} induced by the fatiguing exercise), immediately followed by a 5-s single sprint F-V test to assess the final alteration of F-V-P profile after the 20-s sprint ($P_{\max_END}$, $F_{\max_END}$, $V_{\text{opt_END}}$).

2.3 Statistical Analysis

The main dependent variables were $P_{\max}$, $F_{\max}$ and V_{opt} , derived from the F-V regressions. Baseline values were obtained from the three initial maximal sprints. The values following the one-minute fatiguing exercise (POST-

1MIN) and at the end of the final sprint (END) were derived from the two 5-s F-V tests. Mean power output over the 15-s isokinetic sprint (expressed in $\text{W}\cdot\text{kg}^{-1}$) was used as an index of sprint performance, as it reflects the ability to sustain power over the duration of the effort.

Normality was assessed using the Shapiro-Wilk test. Differences between conditions were assessed using a one-way repeated measures ANOVA. Sphericity was verified using the Mauchly test. Relationships between variables were assessed using Pearson's correlation coefficients (r). Data are presented as mean $\pm$ standard deviation. Effect sizes were reported using partial eta-squared (η^2p), and the level of statistical significance was set at $p < 0.05$.

3 Results

3.1 Effects of One-Minute Fatiguing Exercise and the Final Sprint on F-V-P Profile

The fatigue induced by the one-minute severe effort induced a significant alteration in the F-V-P profile (Table 1 and Figure 1), indicating a greater decline for velocity quality. Additionally, the decrease of $P_{\max}$ was significantly related to the decrease of V_{opt} ($r = 0.58$; $p = 0.047$). A moderate positive relationship was observed between $P_{\max}$ and $P_{\max_POST-1MIN}$ ($r = 0.56$), although this did not reach statistical significance ($p = 0.056$).

A further decline in the F-V-P profile (Table 1 and Figure 1) was observed at the end of the final sprint, indicating a parallel shift in the profile. The decrease of $P_{\max}$ from the beginning to the end of this final sprint was significantly related to the decrease in V_{opt} ($r = 0.71$; $p = 0.009$).

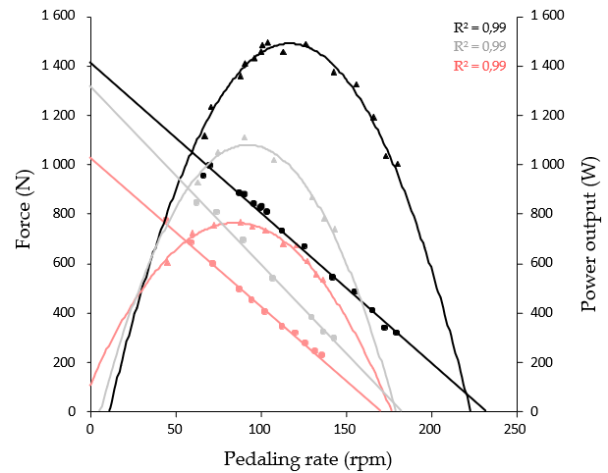


Figure 1. Force-velocity curves (filled circle) and power-velocity curves (filled triangle) for subject n°4. The initial maximal F-V-P profile is shown in black, the profile immediately after the one-minute fatiguing exercise in grey, and the profile after the 20-s final sprint in light red. The R^2 values refer to the linear force-velocity relationships.

3.2 Relationships with Sprint Performance and Fatigue Responses

The 15-s average power output during the final sprint, was strongly correlated with $P_{\max_POST-1MIN}$ ($r = 0.93$; $p = 0.001$). It was also inversely correlated with the decrease in $P_{\max}$ from $P_{\max_POST-1MIN}$ to $P_{\max_END}$ ($r = -0.91$; $p = 0.001$).

Table 1. Mean $\pm$ SD values of maximal power ($P_{\max}$), maximal force ($F_{\max}$), and optimal cadence (V_{opt}) determined from the Force-Velocity-Power (F-V-P) profile in the initial, post one-minute fatiguing exercise (POST-1MIN), and post-sprint conditions (END). Percentage decreases between conditions are also reported. * Significant decrease from the initial profile ($p < 0.001$); # significant decrease from POST-1MIN profile ($p < 0.001$). Effect sizes between conditions were all > 0.81 (η^2p).

	Initial F-V-P profile	POST-1MIN F-V-P profile			END F-V-P profile		
	Mean $\pm$ SD	Mean $\pm$ SD	%		Mean $\pm$ SD	%	%
$P_{\max}$ ($\text{W}\cdot\text{kg}^{-1}$)	18.4 $\pm$ 1.2	13.8 $\pm$ 1.5	-25 $\pm$ 7*		10.4 $\pm$ 0.5	-43 $\pm$ 3*	-18 $\pm$ 7#
$F_{\max}$ ($\text{N}\cdot\text{kg}^{-1}$)	17.6 $\pm$ 1.0	16.0 $\pm$ 1.1	-9 $\pm$ 7*		14.0 $\pm$ 0.9	-20 $\pm$ 7*	-11 $\pm$ 7#
V_{opt} (rpm)	117 $\pm$ 5.3	97 $\pm$ 9.3	-17 $\pm$ 7*		84 $\pm$ 6.4	-29 $\pm$ 5*	-11 $\pm$ 7#

4 Discussion

The one-minute fatiguing exercise induced a change in the F- V-P profile consistent with the observations of Buttelli et al. (1997), with a greater reduction in the velocity component than in the force component (-17% for V_{opt} versus -9% for F_{max}). However, unlike their findings, the decrease in F_{max} was significant in the present study. The greater reduction in P_{max} observed in the present study ($-25 \pm 7\%$ compared with $-13 \pm 6.5\%$ in Buttelli et al., 1997) may be explained by the nature and higher intensity of the fatiguing exercise. In this context, Robin et al. (2021) reported variations in P_{max} from -29.2% to $+1.5\%$ in a competitive setting, with an average power output of $6.1 \pm 1.0 \text{ W}\cdot\text{kg}^{-1}$ (slightly lower than the one-minute fatiguing exercise intensity used in the present study) in the final minute, suggesting that the extent of fatigue depends heavily on the specific demands of the preceding effort.

The strong correlation between the average power output during the final 15-s sprint and $P_{max_POST-1MIN}$, combined with the absence of correlation with P_{max} (i.e. in free fatigue condition), suggests that the ability to maintain a high level of P_{max} following a severe effort is a key factor in sprint performance. Furthermore, although P_{max} endurance is considered a factor influencing sprint performance, there is no association here, because there is a strong inverse correlation between $P_{max_POST-1MIN}$ and the decline in power during the 15-s sprint, which underlines the importance of the level of $P_{max_POST-1MIN}$ available at the start of the final effort. The fact that this $P_{max_POST-1MIN}$ was more influenced by the decrease induced by the preceding effort than by maximal F-V-P capacity suggests that efforts preceding the final sprint in a race situation specifically alter athletes' mechanical capacity, independently of their maximal F-V-P profile.

Finally, the marked decrease in V_{opt} and the decrease in P_{max} induced by the one-minute fatigue exercise was mainly related to this reduction in V_{opt} , which is original and unexpected. This highlights the importance of the ability to limit the decline in the velocity component for maintaining performance under fatigued conditions.

5 Practical Applications

This study provides practical insights into changes in the F-V-P profile during a final sprint in road cycling races. It shows that an intense fatiguing effort has a significant impact on sprint mechanical capacity, particularly through a reduction in V_{opt} . It is therefore essential to individualize strategies for optimizing gear ratio and cadence. In competition, selecting a gear ratio that allows riders to maintain an optimal cadence range, considering changes due to fatigue, can help them maintain efficient power output during the entire sprint.

However, this study has certain limitations. The small sample size ($n = 12$) will need to be expanded to around 18 participants in order to increase the statistical power, particularly for detecting moderate effects. Furthermore, the one-minute exercise protocol, which was conducted under controlled conditions on an ergometer, may not fully reflect the complexity of real-world running situations.

Future research should aim to better understand the mechanisms associated with changes in the F-V-P profile, as well as methods for reducing the effect of pre-sprint fatigue in road cycling, in particular using different pre-fatigue protocols with varying intensity profiles.

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

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