Force-velocity components of the critical power in non-cyclists, recreational trained and elite cyclists

Yann Bertron[1], Pierre Samozino[1], Maximilien Bowen[1], Alexandre Abel[2], Jean-Baptiste Quiclet[2], Frédérique Hintzy[1], Baptiste Morel[1]

[1] Univ Savoie Mont Blanc, Inter-university Laboratory of Motricity Biology, EA 7424, F-73000 Chambéry, France

[2] Ag2r – Citroën Team, UCI WorldTeams

Corresponding author: baptiste.morel-prieur@univ-smb.fr

ABSTRACT

Background:

The intensity-time relationship describes that the highest intensity that can be sustained for a given time decreases when exercise duration increases but converges towards an intensity-asymptote (Monod & Scherrer 1965). This asymptote has been referred as the critical power. The second parameter describing this relationship is a curvature constant which represents a fixed amount of work (W’) that can be mobilized above the critical intensity (i.e. a reserve). The critical power and W' have proven to be robust measurements allowing cyclists to predict their tolerable duration and power output within the severe intensity domain (Poole et al. 2016) and can be estimated through a 3min all out test (Vanhatalo et al. 2007).

Mechanically, the power corresponds to the product of force and velocity (expressed in cadence). Thus, a similar power can be produced with more force - less velocity, and vice versa. The Force-Velocity relationship describes the force and velocity components of the maximum power output (Vandewalle et al. 1987). Although this has been extensively studied for maximum intensity exercise realized in fresh conditions, the part of force or velocity capacities that composed the critical power has never been investigated. This may provide new insight to better understand the

determinants of the critical power and characterized different training level or individual profiles. Furthermore, the critical power is usually evaluated without considering the cadence at which it is produced. It could thus exist different critical power values according to the cadence, which may induce a difference between the critical power measured at a given cadence and the true maximal critical power that can be produced at a critical optimal cadence.

Therefore, the aim of the present study was i) to analyze the force-velocity components of the power produced at the end of a three minutes all-out cycling exercise non-cyclists, sub elite trained cyclists and elite cyclists and ii) to determine whether the 3min all out end-test power underestimate the maximal power that can be produced at this time.

Method: The study included 49 participants divided into 3 groups: 21 moderately active but not cyclists (NC – 20 to 24 years old, 4.8 ± 2.9 h/week of training load), 19 sub elite trained cyclists (SC – 20 to 24 years old, 10.0 ± 2.9h/week) and 9 elite (5 professionals and 4 elite under 23) cyclists (EC, 18 to 30 years old, 25.5 ± 7.2h/week). All of them participated in one experimental session but 11 of the NC group came twice for a reproducibility analysis.

Participants realized a standardized warm-up (cycling at a comfortable cadence during 5, 3 and 1 min at 1, 3 et 5 $W.kg^{-1}$ respectively). Then, they performed three 5-s cycling sprints with a randomized friction force fixed at 3, 6 and 9% of body weight (rest = 3 min). Mean pedal stokes force and velocity were fitted with a linear model so to obtain the initial force-velocity relationship characterized by initial theoretical maximal force (F_{0i}) and velocity (V_{0i}). The maximal power was calculated (Vandewalle et al. 1987) as follows:

$$P_{max} = 0.25 \cdot F_0 \cdot V_0$$

The optimal cadence correspond to the cadence at which Pmax is produced, and calculated as the half of V_0. Then, participants performed a 3-min all-out test on a friction load cycloergometer with a friction set at 25% of F_{0i}. End test power (EP) was defined as the average power during the last 30s of the all-out test (Vanhatalo et al. 2007) Thirty seconds before the end and at the end of the test the experimenter pulled the friction belt so the flywheel stopped instantaneously. Since the participants were asked to never stop their maximal effort (i.e. no rest), they accelerated the flywheel after each brake until they reached the maximal cadence they can (~5 seconds). End-test force-velocity relationship was determined using mean pedal strokes force and velocity from these two end-test sprints. End-test theoretical maximal force, velocity and power (F_{0e}, v_{0e} and EP_{max}) were then determined.

Results: F_{0e}, V_{0e} and EP_{max} demonstrated excellent between day reliability with ICC being 0.94, 0.95 and 0.93 and SEM of 3.3, 3.9 % and 4.2%, respectively. Initial and end-test V0 and F0 for each group are presented in table 1. When expressed relatively to initial values F_{0e} and V_{0e} were not correlated. EP (4.64 ± 1.01 $W \cdot kg^{-1}$) was significantly lower than EP_{max} (5.67 ± 1.01$W \cdot kg^{-1}$; $p < 0.001$). The quartiles of the relative difference between EP and EP_{max} were Q1: -24.6%; Q2: -17.0% and Q3: -9.6%.

Table 1. force-velocity relationship's parameter for Initial and end-test conditions. a, b and c: statistically different from NC, SC and EC, respectively.

Group	F0i ($N \cdot kg^{-1}$)	V0i (rpm)	F0e ($N \cdot kg^{-1}$)	V0e (rpm)
NC	2.16 ± 0.28 [c]	266 ± 25 [c]	1.40 ± 0.24 [c]	142 ± 24 [b,c]
SC	2.22 ± 0.20 [c]	253 ± 24 [c]	1.39 ± 0.19 [c]	174 ± 20 [a]
EC	3.02 ± 0.23 [a,b]	230 ± 8 [a,b]	1.68 ± 0.14 [a,b]	166.19 [a]

Discussion: F_{0e}, V_{0e} and EP_{max} parameters presented excellent between-day reliability. Thus, the present study extended the previously known reliability of EP to the whole end-test force-velocity relationship.

Considering velocity component, V_{0i} was lower and V_{0e} was higher for SC compared to NC and EC compared SC. Higher trained cyclists may present higher slow twitch fiber proportion which present lower velocity contraction capacity but higher resistance to fatigue. For the force component, elite athletes present higher initial and end-test F_0 normalized to body mass which is certainly due to their very low-fat mass. There was no correlation either between F0e and V0e when expressed relatively to the initial values nor between initial and end-test F_0 and V_0. This means that the force and velocity component of maximal end-test power are both independent the one from the other and from initial fresh conditions.

EP_{max} was statistically higher than EP, because the cadence during the final phase of the test was not necessarily the optimal one. EP_{max} appears to be a better indicator than EP, because it is independent from the cadence reached at the end of the test contrary to EP. Furthermore, an important variability in the difference between EP_{max} and EP have been observed (between 0 and 45%; median = 17%) which indicates that maximal end-test power can be more or less underestimated with the traditional 3min all-out test. For instance, figure 1 shows that i) cyclists with different EP may actually present similar EP_{max}, and ii) cyclists with similar EP may present different EP_{max}.

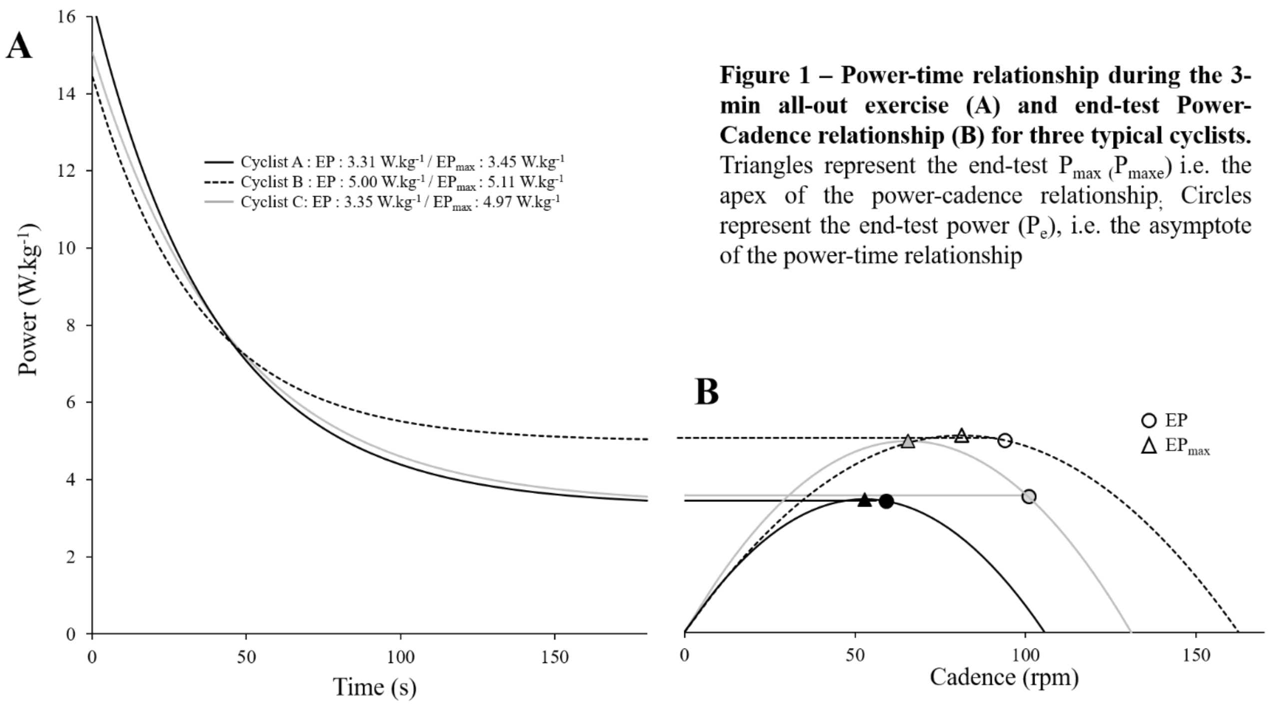

Figure 1 – Power-time relationship during the 3-min all-out exercise (A) and end-test Power-Cadence relationship (B) for three typical cyclists. Triangles represent the end-test P_{max} (P_{maxe}) i.e. the apex of the power-cadence relationship. Circles represent the end-test power (P_e), i.e. the asymptote of the power-time relationship

Practical Applications: Considering a critical power-velocity relationship may be useful for athletes and coaches as it allows i) to determine the maximal end-test power independently from the end-test cadence as well as the 'critical' optimal cadence to reach the maximal critical power and ii) to quantify the force and velocity component of critical power in order, for instance, to individualize and orient the training of one of these muscular capacities.

References

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