Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

OPEN ACCESS

Communication

Maximal aerobic power-cadence relationship estimation in national level under nineteen cyclists from *in-situ* data

BERTRON Yann[1], BOWEN Maximilien[1], LEO Peter[2], SAMOZINO Pierre[1], PACOT Alexandre[3], HINTZY Frédérique[1] and MOREL Baptiste[1].

[1] University of Savoy – Mont – Blanc, Laboratory Interuniversity of Motricity Biology
[2] Division of Performance Physiology & Prevention, Department Sports Science, University of Innsbruck.

[3] Ag2r – Citroën u19 team, Plus de Sports, 38500 Voiron, France.

* Correspondence: BM. baptiste.morel-prieur@univ-smb.fr

Received: date; Accepted: date; Published: date

Abstract: For any given duration, the cyclist performance capacities can be determined with based on a power profile i.e. mean maximal power (MMP). Power is a product of torque and cadence, and maximal efforts in cycling can be modeled by a polynomial relationship between maximal power (P_{max}), optimal torque (T_{opt}) and the optimal cadence (C_{opt}). The objective of this research is to explore the torque- and power – cadence relationship for MMP 5-min (as a surrogate of maximal aerobic power, MAP MMP 5-min data for al cadences between 60 and 120rpm were analyzed accordingly) on 14 national-level cyclists (17 ± 1 years, 66.9 ± 4,4 kg, 11h00min ± 1h30min of training/week). The goodness of fit was excellent (r^2 = .90 [.82-.94]). The even-odd days intraclass correlation coefficient (ICC) were very high for T_{opt} and P_{max} (.90 and .94, respectively) and high for C_{opt} (.76). Standard Error Measurement (SEM) was 2.2 N·m^{-1} for T_{opt}, 4.3 rpm for C_{opt}. and 10.8 W for P_{max}. Mean optimal torque values was 42.6 ± 7.0 N·m^{-1} and the mean optimal cadence – rate was 91rpm ± 8 rpm. The estimated 5-min MMP was 402 ± 40 watts. Thus, the MMP 5-min – cadence modeling is feasible, reliable and produce coherent indicators of cycling performance. This modelling gives important information, such as optimal torque and cadence. Numerous applications for testing, training and racing could be extracted from this innovative approach.

Keywords: Maximal Mean Power; torque-power-cadence relationship; optimal cadence; maximal aerobic power

1. Introduction

Power output is frequently used in cycling by athletes, coaches and sport scientists to evaluate performance, determine race demands and to provide training prescriptions. For a given duration, the cyclist physical capacities can be determined with the mean maximal power (MMP) recorded over a prolonged period of time (e.g. a season) from power meters (Leo, Spragg, et al. 2020; Sanders and Van Erp 2020). For instance, the MMP 5-min record is generally associated to the MAP (Allen and Coggan 2010).

Power is mechanically the product of the crank torque in N.m^{-1} and angular velocity in rad·s^{-1} (eq. 1) the latter being usually expressed in cadence (rpm). During maximal efforts, a polynomial relationship exists between power and cadence:

$$(1) \quad P(c) = \left[C_0 \cdot \left(1 - \left(\frac{C}{C_0}\right)\right)\right] \cdot C$$

with P being the power, C_0 the maximal cadence a null torque and T_0 the maximal torque at null velocity. A maximal power production being possible only with an optimal cadence (C_{opt}) and torque (T_{opt}) being respectively half of C_0 and T_0 (Dorel 2018; Vandewalle et al. 1987) . This means that any other pedaling rate will automatically lead to non-maximal power output values despite maximal voluntary intensity. Although torque - power and cadence profiling has been mainly reported from laboratory conditions during sprint cycling efforts (Dorel 2018), the torque- power and cadence relationship might also relate to prolonged exercise duration in form of a polynomial function (Zoladz, Rademaker, and Sargeant 2000).

The aim of this study was to test the feasibility to model the power-cadence relationship for the 5-min MMP and to verify its reliability by means of comparing odd and even days.

2. Materials and Methods

Subjects — Fourteen male under 19 national level cyclists participated in this study, (17 ± 1 years, 66.9 ± 4,4 kg, 11h00min ± 1h30min of training/week) and competed at national and international level races of the 2019-2020 or 2020-2021 seasons. This is a retrospective study which uses existing data. This is a retrospective study which uses existing data. The database was collected and declared accordingly to the European General Data Protection Regulation.

Design—The present study proposes a retrospective analysis of the data recorded during one complete season of national under 19 level with time, power, cadence data registered by the participants mobile power meter (Quarq Dzero, West Fulton Market, Chicago, USA) and head unit (Wahoo ROAM, West Wieuca Rd NE, Atlanta, USA). Data were stocked into a database and then treated on Matlab software ®(R2021a).

Methodology— We computed the MMP for a duration of 5-min and for each mean cadence between 60 and 120 rpm and for each training session or race. To test the reliability of the proposed methodology, the data from odd and even days were processed separately with the same algorithm: (i) selection of the MMP 5-min for each cadence over the season; (ii) conservation of a MMP is it is the highest torque of all higher cadence and the highest cadence of all higher torque; (iii) fitting of the polynomial model on the remaining data. These steps are illustrated in Figure 1.

Statistical Analysis – Data consistently passed the normality test (the Shapiro-W ilk's test), therefore results were expressed as mean ± SD. Goodness of the fit will be tested by reporting median and quartiles of the coefficient of determination (R^2). Odd-even days absolute and relative reliability will be measured by means of ICC and absolute SEM, respectively for C_{opt}, T_{opt} and P_{max}.

3. Results

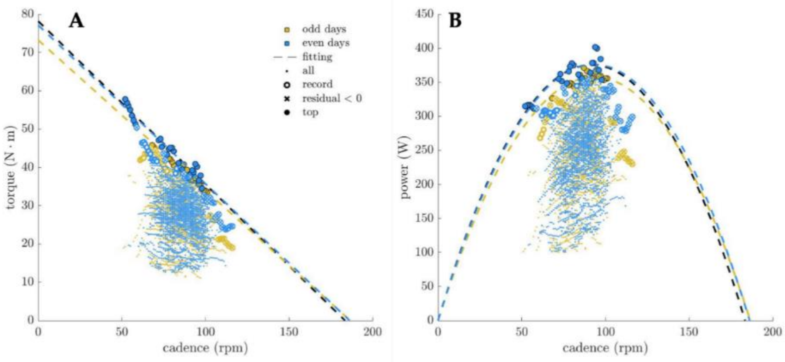

Figure 1. Torque – Cadence relationship (A) obtain from training and racing data for odd days (yellow circles) and even days (blue circles), with bold circle represent the torque – cadence record points. Power – Cadence relationship (B) modeled from the Torque – Cadence relationship, expressed in power.

For MMP 5-min, mean T_{opt} was 42.6 ± 7.0 N·m-1 and the C_{opt} was 91rpm ± 8rpm. This correspond to a P_{max} of 401 ± 39 W (Figure 2).

The goodness of the fit was excellent (r^2 = .90 [.82-.94]). The even-odd days ICC were very high for T_{opt} and P_{max} (.90 and .94, respectively) and high for C_{opt} (.76). (SEM

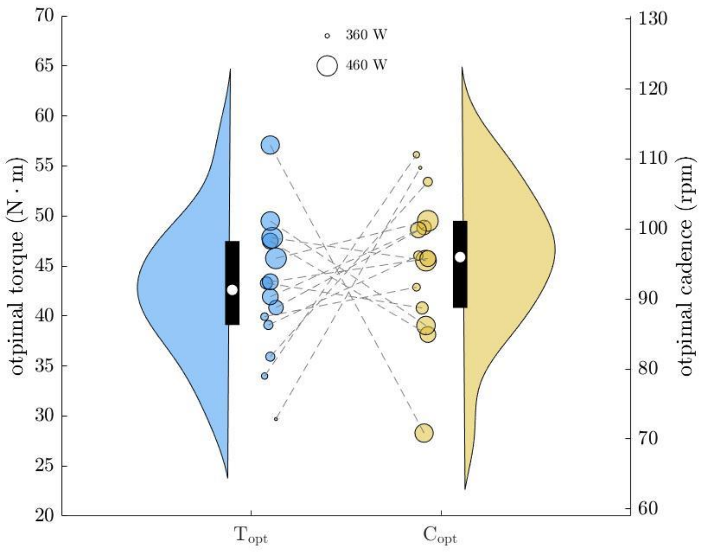

Figure 2. Optimal torque and cadence Violin plot for 5-min MMP. Dashed lines link each individual. P_{max} is represented by means of dot radius.

was 2.2 N·m-1 for Topt, 4.3 rpm for C_{opt}. and 10.8 W for P_{max}.

4. Discussion

The objective of this study was to test the feasibility to model the torque-, power- and cadence relationship for the 5-min MMP and to verify its reliability by means of comparing odd and even days. The main results are that the power-cadence relationship for MMP 5-min showed very high goodness of the fit and odd-even days reproducibility.

MMP 5-min torque-, power- and cadence relationship reported a mean P_{max} value of 402 watts (± 40) for national level under 19. This is in line with previous studies reporting 397w on a future grand tour contender when he was an under 19 (Pinot and Grappe 2015). These data are also logically slightly below the 444 watts for under 23 (Leo, Giorgi, et al. 2020). and 432 watts for elite and professional athletes (Pinot and Grappe 2011). Furthermore, optimal cadence derived from the MMP 5-min torque-, power- and cadence relationship was 91 rpm which is close to the cadence used by elite cyclist during near maximal aerobic effort being 89 rpm (Bouillod and Grappe 2017).

5. Practical Applications.

As illustrated from Figure 2, very high variability can be observed between T_{opt}/C_{opt} for each individual. The same maximal power can be produced with different torque/cadence profiles. Numerous applications for testing, training and racing could be extracted from this innovative approach such as to test the ability of a cyclist to voluntary select optimal cadence rate, to prioritize torque vs. cadence training based for the individual aerobic torque-cadence profile or to assist for gear selection.

6. Conclusions

Thus, the MMP 5-min torque- and power-cadence modeling is feasible, reliable and produce coherent indicators of performance (maximal power, optimal cadence) for under 19 elite cyclists.

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

References

Allen, Hunter., and Andrew. Coggan. 2010. "Training and Racing with a Power Meter." 326.

Bouillod, Anthony, and Frederic Grappe. 2017. "Physiological and Biomechanical Responses between Seated and Standing Positions during Distance-based Uphill Time Trials in Elite Cyclists." *Https://Doi.Org/10.1080/02640414.2017.1363902* 36(10):1173–78. doi: 10.1080/02640414.2017.1363902.

Dorel, Sylvain. 2018. "Maximal Force-Velocity and Power-Velocity Characteristics in Cycling: Assessment and Relevance." *Biomechanics of Training and Testing: Innovative Concepts and Simple Field Methods* 7–31. doi: 10.1007/978-3-319-05633-3_2.

Leo, Peter, Andrea Giorgi, Dan Lorang, James Spragg, Iñigo Mujika, and Justin Lawley. 2020. "Workload Characteristics and Race Performance of U23 and Elite Cyclists during an UCI 2. Pro Multistage Race (Tour of the Alps)."

Leo, Peter, James Spragg, Dieter Simon, Justin S. Lawley, and Iñigo Mujika. 2020. "Training Characteristics and Power Profile of Professional U23 Cyclists throughout a Competitive Season." *Sports*. doi: 10.3390/sports8120167.

Pinot, Julien, and Frederic Grappe. 2015. "A Six-Year Monitoring Case Study of a Top-10 Cycling Grand Tour Finisher." *Journal of Sports Sciences*. doi: 10.1080/02640414.2014.969296.

Sanders, D., and T. Van Erp. 2020. "The Physical Demands and Power Profile of Professional Men's Cycling Races: An Updated Review." *International Journal of Sports Physiology and Performance* 16(1):3–12. doi: 10.1123/IJSPP.2020-0508.

Vandewalle, H., G. Peres, J. Heller, J. Panel, and H. Monod. 1987. "Force-Velocity Relationship and Maximal Power on a Cycle Ergometer - Correlation with the Height of a Vertical Jump." *European Journal of Applied Physiology and Occupational Physiology*. doi: 10.1007/BF00424805.

Zoladz, Jerzy A., Arno C. H. J. Rademaker, and Anthony J. Sargeant. 2000. "Human Muscle Power Generating Capability During Cycling at Different Pedalling Rates." *Experimental Physiology* 85(1):117–24. doi: 10.1111/J.1469-445X.2000.01840.X.