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Conference Abstract

Maximum Power Available: An Important Concept for Prediction of Task Failure and Improved Estimation of Training Loads in Cycling

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Abstract: Predicting improvements in cycling performance requires accurate quantification of the parameters of the power-duration relationship and detailed understanding of the training load-performance relationship. Existing models simplify training stress into single metrics, overlooking diverse responses to intensities and their time-dependency. The theoretical framework for the concept of Maximum Power Available (MPA) is described in this presentation. MPA is used to quantify instantaneous training stress and predict task failure in cycling. It employs a modified 3-parameter critical power model capable of fitting intermittent data to quantify the parameters of the power-duration relationship, relying solely on the W′ balance differential model. Rather than W′ balance = 0, task failure is defined as MPA reaching the task work rate. Since work generates fatigue which affects MPA, it may be used to derive more valid training load metrics when compared with other training load metrics. By applying the three-dimensional nature of the power-duration relationship to exercise stress, this model provides a more comprehensive model both for the power-duration relationship and the training load-performance relationship, with the potential to facilitate more effective training program design and performance optimization.

Keywords: Critical Power, Modeling, High-Intensity Training, Training Load

1. Introduction

The popular critical power (CP) model defines the highest power output sustainable by oxidative energy production, and the curvature constant (W′) comprises the finite energy reserve available above CP (Poole et al., 2016). Extending the simple two-parameter model to a 3-parameter model by adding a ceiling for instant power output (Pmax) improves modeling of performance for short durations (Morton et al., 2006). Pmax is only reached in a non-fatigued state; depletion of W′ leads to Pmax being unachievable, and a dynamic ceiling for the maximum instantaneous power. This concept of Maximum Power Available (MPA) may be derived from the 3-parameter model to assess instantaneous training stress and prediction of task failure. Furthermore, the proposed, modified 3-parameter CP model is capable of fitting intermittent data relying solely on the W' balance differential model, which is then used to calculate MPA; task failure is defined as MPA reaching the task work rate. MPA may also be used to derive more valid training load metrics and to estimate training load for each energy system separately to better model fitness and fatigue using impulse-response models.

The purpose of this presentation is to 1) outline and define the MPA concept; 2) provide theoretical and experimental evidence for its validity; and 3) illustrate how a power-based training load metric derived from the MPA concept better reflects metabolic stress than popular alternatives currently used.

2. Materials and Methods

1) A novel mathematical model for MPA, initially based on the existing 3-parameter critical power model, was derived by iteration of best fit to field data collected using power meters. The proximity of instantaneous power output to MPA was used to predict task failure and to estimate temporary metabolic stress.

2) 19 well-trained cyclists performed a Pmax test, a 20-s sprint test, and separately five time trials (TT; 1, 3, 6, 12, and 30 min) on a cycle ergometer to establish points along the power-duration relationship. The data were fitted into the existing 2- and 3-parameter CP models (2P and 3P; Equation 1 and 2) and a modified 3-parameter model (3PMod; Equation 3) using least squares mean maximal power fitting, and for the 3P models, also by using a novel method that compares model-derived intermittent MPA data with power data from the TT tests in formulating a least absolute regression fit.

3) Resulting training load values for simulated cycling sessions were then compared to popular existing training load metrics (work, Training Stress Score®).

$$t = \frac{W'}{P - CP} - \frac{W'}{Pmax - CP}$$

Equation (1)

$$MPA = Pmax - (Pmax - CP) \cdot \frac{W'exp}{W'}$$

Equation (2)

$$MPA = Pmax - (Pmax - CP) \cdot \left(\frac{W'exp}{W'}\right)^2$$

Equation (3)

3. Results

3.1. Experimental results

Power-duration data over a wide range of durations were better fitted by both 3-parameter models than the 2-parameter model. CP estimates by the three models were highly correlated (0.95<r<0.99), but W′ estimates showed lower correlations between the 2-parameter model and 3P and 3PMod (r=0.71 and r=0.70, respectively; r>0.99 between 3P and 3PMod). Parameter estimates for each model are given in Table 1.

Table 1. Model parameters derived from the experimental time trials.

Model	CP (W)	W' (kJ)	Pmax (W)
Linear W-t 2P (3-12min)	258 (44)	22.7 (5.1)	N/A
3P (1s-12min)	245 (38)	29.9 (7.7)	1232 (200)
3PMod (1s-12min)	254 (40)	24.1 (5.7)	1201 (195)

Using the novel MPA fitting method considerably higher CP values were obtained and differences between the 3P and 3PMod models were observed: The model fit that included (PI) the intermittent data collected during the Pmax test resulted in a lesser adjustment of CP and Pmax in 3PMod (Table 2).

Table 2. Model parameters using MPA least absolute deviation regression.

Model	CP (W)	W' (kJ)	Pmax (W)
3P	260 (38)	29.9 (9.1)	1227 (194)
3PMod	274 (44)	21.2 (5.0)	1193 (189)
3P (PI)	272 (43)	27.5 (9.3)	1421 (260)
3PMod (PI)	280 (42)	20.3 (4.7)	1240 (207)

3.2. Training load simulation

Comparison of training load calculations for 20-min constant load (20CL) exercise and 20x1-min intermittent exercise showed that calculating load with the MPA-derived method (Xert Strain Score, XSS) aligned better with the physiological reality of increasing metabolic stress as a function of time in the severe domain (XSS 20CL > XSS 20x1), than calculating training load with TSS® (TSS 20CL < TSS 20x1) or work completed (W 20CL = W 20x1).

4. Discussion

The results of the present study highlight the importance of the incorporation of Pmax into critical power models for better prediction of task failure in both constant-load and intermittent exercise. Selection of included trials affect the parameters and performance of the models.

5. Practical Applications

The novel MPA concept allows for i) determination of a 3-parameter CP model parameters from data with maximal efforts; ii) improved precision of systems modeling of performance by allocating training loads for CP, W', and Pmax; iii) a potential way of quantifying training loads with improved accuracy based on modeled instantaneous metabolic stress.

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Conflicts of Interest: A.M. is the founder and majority shareholder for Baron Biosystems. S.C. is the Chief Sport Scientist for Baron Biosystems and is a minority shareholder.

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