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Analysis of Mean Maximal Power in cycling with a modified Critical Power model allowing for a non-constant Anaerobic Work Capacity

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Abstract

Introduction: Since its introduction by Monod and Sherrer[1] the Critical Power model has been applied to the analysis of cycling performances. In this model the Critical Power CP is the highest power that can be sustained without fatigue, and the total amount of work that can be produced until fatigue at any level above CP is indicated as the anaerobic work capacity W'. As yet W' is considered to be a constant quantity. However Mean Maximal Power data, indicated by MMP, or a (t_{lim},P_{lim}) data set can by described adequately by this CP-model only in a limited time range, typically between t_{lim}=20' and t_{lim}=60'. Although the model can also formally be applied to short efforts, the relevant parameters CP and W' as obtained from short and long efforts will differ significantly. Therefore we propose a modified CP-W' model that will describe the MMP curve for the full relevant time range.

Theory and results: The standard critical power model is expressed as $P(t) = CP + \frac{W'}{t}$ where t is the limiting time that a power P can be sustained until exhaustion. This equation is valid for all values of P(t) > CP but it leads to a catastrophe for short sustainable times because $\lim_{t\to 0} P(t) = \infty$ Therefore some authors have proposed a general modification $P(t) = CP + \frac{W'}{t} f(t)$ where the function $f(t)$ has to be chosen such that $\lim_{t\to 0} P(t) = P_{max}$ and P_{max} is the zero-extrapolated maximal power. The effective work that can be delivered above CP is then $W_{eff} = W'f(t)$. Examination of a number of MMP curves have lead us to consider 2 sustainable time zones, each zone being described with an appropriate correction function *f(t)*. The full MMP curve is described as

$$P(t) = \left\{CP + \frac{W'}{t}\left[1 - \left(1 - {t}/{T_{SCP}}\right)^2 U(T_{SCP} - t)\right]\right\} U(t - tsw) + \left\{MAP + \frac{W_S'}{t}\left(1 - e^{-t/\tau}\right)\right\} U(tsw - t)$$

Where U(t) is the unit step function i.e. U(t≥0)=1 and U(t<0)=0, where tsw is the switching time between short and long sustainable time regimes, T_{SCP} is the cut-off time that identifies the time below which the classical Monod-Sherrer model breaks down, W_S' is the maximal total work that is produced above MAP, the time constant $\tau = W_S'/(P_{max} - MAP)$ describes de decrease of sprinting power.
The first part for t≥tsw is identical to the classical CP model for all times above T_{SCP} ; for times between T_{SCP} and tsw the CP model becomes increasingly inadequate. Supercritical power SCP is the power corresponding to the onset of this failure at T_{SCP}. The second part (t<tsw) is in agreement with the findings of Péronnet and Thibault[2] who analyzed the historical running performances and world running records. The full set of primary parameters to be fitted to the experimental MMP data is (CP,W',T_{SCP},MAP,τ,P_{max}). We obtained the MMP data for a world class grand tour cyclist. The MMP was constructed from all his training and competitive bouts over the whole 2014 season. The MMP was digitized into 11 experimental pairs (t_i, P_i) and is shown in figure (1) as well as the best fit theoretical function P(t). The curve shows 2 asymptotic tendencies e.a. towards MAP = 7.89 W/kg, and towards CP = 5.01 W/kg. All laboratory tests to determine CP with typical exhaustion times between 3' and 12' will inevitably yield a value much higher than CP and closely related to MAP.
After a proper determination of CP experimental values of W_{eff} are obtained as $W_{eff}(t_i) = [P(t_i) - CP]t_i$ and a plot of $W_{eff}(t_i)$ versus $P(t_i)$ is made as was suggested recently by M. Puchowicz[3]. This plot is shown in figure (2) with a model curve that was constructed from the parameters obtained from the MMP-fitting. The relevant fitted parameters are shown in the inset of the figures.
The cyclist has access to his full W_{eff} of 2.51 kJ/kg for all intensities up to his supercritical power SCP = 6.91 W/kg. For higher intensities W_{eff} drops dramatically and reduces eventually to 0 at P_{max} = 22.2 W/kg. For any sustainable time t < Tscp and intensity > SCP the available W_{eff} is much lower than the saturation value. This indicates that for this cyclist any test at sustainable times shorter than Tscp = 22 minutes will inevitably lead to anomalously high values of CP and low values of W'.

Conclusions: We have presented a new model describing the full MMP-curves. Detailed analysis of the MMP and the [P,W'] data yield a set of field-based power parameters CP, W',SCP,T_{SCP}, MAP, P_{max}, τ. This model lifts the long standing discrepancy between the determinations of CP from short or from long efforts. CP from short test is closely related to MAP, while CP from long times is related to Maximal Lactate Steady State. CP test should be performed in the exhaustive time interval where W_{eff}' has a constant value, i.e. for times higher than T_{SCP}. Further research may focus on the relevance of these objective parameters for qualifying the strengths of sprinters, punchers, time trialists and climbers.

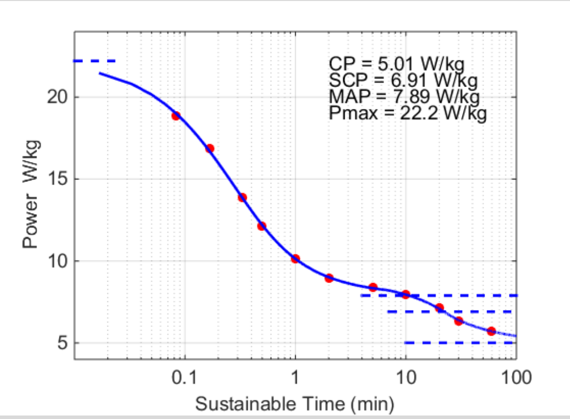

Figure 1. MMP data and fitted curve and indication of reference power values.

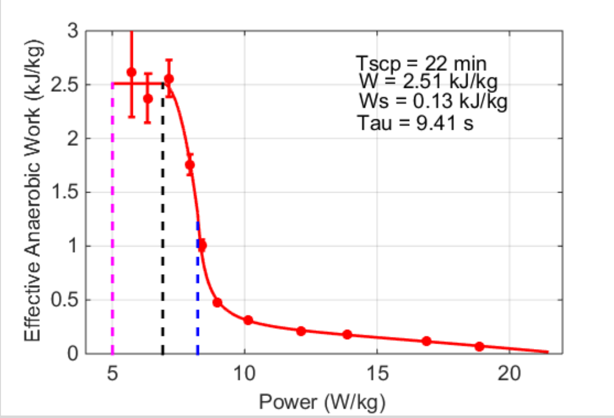

Figure 2. Decline of the effective anaerobic reserve with increasing power

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