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BOOK OF ABSTRACTS **Open Access**

Application to cycling of a bioenergetic model: Towards a multi-level biomechanical model for global cyclist performance analysis

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Abstract

Introduction: Models of bioenergetic systems are developed to explain how a biological system behaves while interacting with the environment. Recent attempts in sport science research advocate the evidence-based training prescription and performance assessment and help in translating laboratory-based research into real world practice by the means of bioenergetic models. Such models have been developed for cycling activity for constant work rate or intermittent exercise for a single training session (e.g. critical power CP model and reconstitution of the anaerobic work capacity, (Chidnok et al., 2012, Medicine & Science in Sports and Exercise, 44(5), 966-976)), as well as for describing how the performance capacity changes over time (Clarke & Skiba, 2013: Advances in Physiological Education, 37, 134-152). The model here adopted (Moxnes et. al, 2012, Theoretical Biology and Medical Modelling, 9:29) claims to predict both oxygen consumption ($V'O_2$) and lactate production [La]' dynamically at a given power output requirement. In this work we model the bioenergetics processes involved in human exercise and recovery for the case of a cyclist in outdoor training.

Purpose: The aim of this study is to validate the model in order to track the dynamic state of the anaerobic sources accordingly with the CP model (Monod & Scherrer, 1965, Ergonomics, 8, 329-338) and thus predicting by means of numerical simulations the athlete's ability of providing supra-CP power outputs during a training session.

Methods: The symbolic bioenergetic models that include $V'O_2$ and [La]' has been derived according to the work of Moxnes and colleagues (Moxnes et. al, 2012). First set of model's parameters are estimated with an optimization approach to best fit laboratory continuously logged data for a road cyclist during a 4 min graded incremental exercise ([La], $V'O_2$, and mechanical power). Moreover a recent database of mechanical power values recorded during training sessions of the same athlete have been used as further parameters of the model (e.g. maximal mean power and critical power CP). Secondly experimental data have been acquired in outdoor condition by the means of a powermeter (Power2Max) for the mechanical power, a portable metabolimeter (K4, Cosmed) for the $V'O_2$, and a portable lactate analyzer (Lactate PRO) for the lactate concentration. The first set of experimental parameters is adopted as a first trial solution of an iterative non-linear optimization algorithm that searches for the solution (an optimal set of parameters) which minimises the difference between simulated and the outdoor measured in dependence of the mechanical power.

Results: The optimization algorithm gave a set of parameters for best fit the outdoor measurements which differs from the parameters estimated from the laboratory test. Particularly the $V'O_2$ response for a square wave high intensity exercise is underestimated during the onset, is well predicted at the steady state (with a mean square error <1%) and lightly overestimated during the offset phase. For which concern [La] the model predicts the lactate concentration with increasing error as the exercise proceeds. Accordingly to the modelling literature (Sokolowski and Banks, 2010: Modeling and simulation fundamentals: theoretical underpinnings and practical domains, New Jersey: Wiley) a *verification* process has been carried out to determine if the model is an accurate representation of the system. The process highlighted that (a) the differences between real and simulation values (residuals) appear to behave randomly after a normality test; that (b) there is a *very large* (0.8-0.9) correlation coefficient and explained variance from the correlation analysis of residuals and high goodness of fit after a (c) graphical residual analysis.

Discussion: Current simulation model provides useful insights into how power data of training or testing should be interpreted despite the model's limitations. Main mismatches between theoretical model and experimental data are expected especially when important non-linearities are involved such as abrupt changes in mechanical power output requests, transient responses in general, extreme oxygen consumption or lactate concentrations values. A detailed analysis and of model capabilities and possible improvement will be presented.

Conclusion: The current study investigated a mathematical model for the kinetics of aerobic and anaerobic power during a training session at varying intensity. Applying this model for estimating the anaerobic source depletion and the aerobic source utilization over the time and individualize it for different athletes in outdoor conditions is a challenging and interesting task. Starting from this bioenergetic model application, it is reasonable to cautiously conclude that biomechanical modelling can be specifically adopted while trying to predict the response of an athlete to a training load and may help in training programming or in assessing the cyclist's training status. The development of computational models, trying to overcome the difficulties associated with setting up an experimental protocol for multifactorial analysis, is considered as a possible implementation of the multivariate analysis of the performance. A further development will embed this model in a broader multi-level biomechanical model. The final aim of the multi-level model is to include in an whole the most important variables affecting the performance in cycling and to describe the principal mutual interactions among the factors related to different levels of analysis (i.e. mechanical, muscular, physiological-bioenergetic, environmental) for a global performance assessment. A complete model will help in detailing new cyclist assessment guidelines and may have important implications for the planning and real-time monitoring of athletic performance or training loads.

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