**Influence of training load quantification method on the fitness-fatigue model**

Performance improvement is the response of the body to an appropriate combination of training load (TL) and recovery. In order to obtain maximal performance at the right moment, a precisely controlled training program is needed.1 It is thus clear that tracking TL is a vital part of working with athletes. However, today there are numerous possible ways of quantifying TL, making it difficult for practitioners to choose the most appropriate method.2

In general the methods are described as either external TL (e.g., power, distance, speed) or as internal TL (e.g., heart rate (HR), rating of perceived exertion (RPE)). Where an external TL is a given amount of work the athlete undertakes, the internal TL is the psychophysiological effect that this external TL has on the athlete.3 Most TL quantification methods are a result of multiplying the duration of a training with the intensity of that session. This multiplication is performed to ensure that the TL of short high intensity sessions is not overruled by longer, low intensity sessions. It is the difference between the TL methods in quantifying the intensity of a session that is of greatest concern to coaches and scientists. It is suggested that internal TL is more appropriate to monitor the training process as it is the internal training stimulus that determines training adaptation.3 However, recent technological developments (e.g., TrainingPeaks and GoldenCheetah) have made external TL measures increasingly popular. In this regard, the training stress score (TSS) is the most widely used TL measure in cycling.

In a recent study it is suggested that the best TL method is the one that is relatable to an outcome of importance (e.g., fitness, fatigue or performance).4 Several studies have related different TL methods to performance in a linear way. However, as recently discussed, this linear relationship should be questioned as the interplay between TL and recovery cannot be captured in a simple linear model.5 Mathematical models however, have previously shown promising results in relating TL and performance in athletes.6 Perhaps the most cited mathematical model is the model of Banister.7 This model implies that every training session has both a positive (fitness) and a negative effect (fatigue). It is the difference between these two elements that reflects the performance of an athlete at any given time so that

Performance = Fitness – Fatigue

Although the model of Banister is most referred to, it are actually the refinements of the model by Morton et al.8 and later Busso et al.,9 that led to the formula in the form that is most frequently used

(eq. 1)

The model performance at day () is estimated from successive TLs with ranging from 1 to -1. is an additive term that represents the initial performance level of the subject. and are the exponential time constants, expressed in days, for respectively the fitness and the fatigue term and magnitude factors have been added to both fitness () and fatigue ().

After individualizing the parameters in the model to the specific athlete, it is possible to calculate the influence curves (Fitz-Clarke). These influence curves give us the opportunity to calculate the moment at which training has the greatest influence on performance (tg) and the moment at which training results in a negative impact on performance (tn), denoting the timeframe in which training should be avoided. On the basis of these parameters we can then individualize tapering strategies in order to obtain maximal performance exactly when it is required (Fitz-Clarke).

Over the past decades, the model has been used by researchers in various sports such as swimming1,10-11, running8,12, cycling13-16 and triathlon17-18. Nevertheless, results are inconclusive, showing a high variability in the output parameters and an inability to predict real-world performances in several studies (Taha & Thomas). This variability could be explained by various methodological issues such as limited number of participants, variability in level of subjects and the fact that almost every study uses a different method to quantify TL. Next to this, most of the studies have not been performed in laboratory settings even though data of the highest quality are preferred in systems modelling (Clarke & Skiba).

Therefore the purpose of this study was twofold. The first aim was to test whether the systems model, as proposed in Equation 1, is able to relate TL to performance in an experimental laboratory setting during a recreational cycling training programme. Secondly, we investigated what the influence of different TL quantification methods is on the output parameters of the model, especially with regards to the parameters from which we can derive practical guidelines (i.e. tg and tn).