

# Training at Lactate Threshold: Science Based Concept or Irrational Myth?

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At the beginning of the last century, a systematic stream of well coordinated *in vitro* and *in vivo* experiments led to the theory describing muscular metabolism as an open thermodynamic system [1] with lactate production and respiration as integral factors of metabolic energy production [2]. Shortly later carefully designed experiments analyzing the Blood Lactate Concentration (BLC) at selected testing protocols laid the basis of modern performance diagnostics using BLC measurements [3].

Incremental power tests starting at light or moderate exercise intensity subsequently increase power. Over a range of low power increments the BLC remains more or less at resting level before it increases slowly but progressively during subsequent steps in power. Higher aerobic fitness shifts the corresponding BLC power curve to the right. The first BLC based threshold concept detecting the power at a BLC of 4.0 mmol.l<sup>-1</sup> at a specific testing protocol was termed aerob-anaerobic threshold or 4.0 mmol.l<sup>-1</sup> threshold [4]. It was based upon empirical observations that long lasting constant exercise was sustainable if the BLC stabilized after an initial increase, frequently seen between BLC baseline and 4.0 mmol.l<sup>-1</sup> but rarely above 4.0 mmol.l<sup>-1</sup> [4]. This suggested that 4.0 mmol.l<sup>-1</sup> might detect exercise intensity at or close to the highest prolonged constant power with a constant BLC above resting BLC. Time invariance of BLC indicates a match between rates of glycolytic lactate generation and pyruvate respiration. The highest match between rates of glycolytic lactate generation and pyruvate respiration defines the Maximal Lactate Steady State (MLSS) detected via a series of prolonged constant power tests [5,6]. The between subject variability of both, the MLSS (1.9 to 7.5 mmol.l<sup>-1</sup>) and the MLSS intensity (54 to 83% of incremental peak power) is high and the individual MLSS is rarely found at a BLC of 4 mmol.l<sup>-1</sup> [7]. MLSS may also differ between different sports even if performed by the same athlete [8]. These findings may partly explain why shortly after Mader et al. [4] had published their threshold idea, an excessive number of other threshold concepts were put forward [9,10]. In spite of this still ongoing "threshold inflation" the preciseness of individual MLSS power predictions using selected points on the incremental power test based BLC power curve remains moderate. However, these BLC power curve points are sensitive for changes in aerobic fitness and reflect three BLC orientated intensity domains: 1) light and moderate exercise intensity before the BLC clearly exceeds resting BLC, 2) heavy exercise intensity between initial increase in BLC and MLSS intensity, and 3) severe exercise intensity between MLSS and maximum oxygen uptake intensity.

The idea that a lactate threshold may identify clearly defined exercise intensity was tempting to utilize a specified point on the BLC power curve as orientation for training advice [4]. In moderately trained, untrained or de-conditioned subjects threshold training worked [10]. However, in untrained subjects and recreational athletes also various other training programs were comparably successful [10]. The supposedly rather blunt consideration that endurance training works as long as the mix in exercise intensities accumulates substantial but sustainable metabolic demand irrespective of threshold intensities may get credibility by the fact that successful endurance athletes do not spend much effort on threshold training. Depending on seasonal variations top athletes competing in middle and long distance events train 70 to 90% of their endurance training at intensities corresponding to BLCs below 2 mmol.l<sup>-1</sup>. Also the remaining training includes more

effort at intensities corresponding to BLCs above 6 mmol.l<sup>-1</sup>, which is likely to be higher than usually measured thresholds [10-13]. Based on these observations a number of BLC orientated endurance training zones have been developed. They basically mirror the above mentioned 3 BLC related intensity domains: 1) training up to an intensity before the BLC clearly exceeds resting BLC, equivalent to light and moderate training focusing on active regeneration or high volume endurance work mostly lasting between 1 and 6 hours, 2) heavy endurance training at work rates supposedly up to MLSS intensity lasting 30 to 90 min, and 3) severe exercise intensity training between MLSS and maximum oxygen uptake intensity organized as interval and tempo work normally lasting up to 30 min. Interestingly the volume of training spent on domain 2 is rather low even compared with domain 3 [10-12].

Observations that during short term training interventions in untrained and recreational subjects a focus on intensity domain 2 was comparably successful as various combinations of all three intensity domains is no evidence that threshold training is specifically effective. Training analyses in high performance endurance athletes seem to unmask the idea of training at threshold intensity as a myth without evidence. Whether the latter reflects just the need to link training intensity and volume in order to keep glycogen homeostasis within sustainable limits [10] or also indicates distinct adaptation properties, which are quantitatively only relevant in highly trained individuals close to the limit of their adaptation potential, remains one of the fundamental challenges of Sports Medicine research.

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