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Mathematical analysis of the heart rate performance curve during incremental exercise testing

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In this study we performed laboratory treadmill protocols of increasing load. Heart rate was continuously recorded and blood lactate concentration was measured for determination of lactate threshold by means of $LT_{D\text{-}max}$ and $LT_{4.0}$ methods.

Our results indicate that the shape of heart rate performance curve (HRPC) during incremental testing depends on the applied exercise protocol (change of initial speed and the step of running speed increase, with the constant stage duration). Depending on the applied protocol, the HRPC can be described by linear, polynomial (S-shaped), and exponential mathematical expression.

We presented mathematical procedure for estimation of heart rate threshold points at the level of $LT_{D\text{-}max}$ and $LT_{4.0}$, by means of exponential curve and its relative deflection from the initial trend line (tangent line to exponential curve at the point of starting heart rate). The relative deflection of exponential curve from the initial trend line at the level of $LT_{D\text{-}max}$ and/or $LT_{4.0}$ can be defined, based on the slope of the initial trend line. Using originally developed software that allows mathematical analysis of heart rate-load relation, $LT_{D\text{-}max}$ and/or $LT_{4.0}$ can be estimated without direct measurement of blood lactate concentration.

Keywords: anaerobic threshold, heart rate performance curve, blood lactate

Anaerobic threshold (AT) is the frequently used term for the momentum at which predominantly aerobic metabolism switches to predominantly anaerobic metabolism as a dominant energy source during endurance performance (32). This metabolic shift corresponds to the notable raise of blood lactate concentration (2). Lactate threshold (LT), as one of the most frequently used metabolic indicators of such a metabolic turnover (1), is defined as the point during exercise of increasing intensity at which blood lactate begins to accumulate above resting levels, where lactate clearance is no longer able to keep up with lactate production (15). The changes of blood lactate concentration in estimation of endurance performance are considered as the golden standard to determine the AT (11). Modern terminology has widely accepted the term LT instead of the still controversial term AT (9, 15), and considered it as the workload beyond which blood lactate levels abruptly increase during progressive intensity testing (6).

Meanwhile, certain number of methods for analysis of blood lactate concentration response to exercise has been established in order to allow more precise estimation of endurance performance (16). The most commonly used methods for such analysis are: the onset of blood lactate accumulation – OBLA (34, 37) or $LT_{4.0}$ method (30); maximal lactate steady-state (4, 18); 0.5 method (41); log-log method (25); Dmax method (12, 17); lactate

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