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The mathematical analysis of the heart rate and blood lactate curves during incremental exercise testing

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This paper describes a new mathematical approach for the analysis of HR (heart rate) and BL (blood lactate) curves during incremental exercise testing using a HR/BL curve and its derivatives, taking into account the native shape of all curves, without any linear approximation. Using this approach the results indicate the apperance of three characteristic points (*A*, *B* and *C*) on the *HR/BL* curve. The point *A* on the HR/BL curve which is the value that corresponds to the load (12.73 ± 0.46 km h^{-1}) at which BL starts to increase above the resting levels (0.9 ± 0.06 mM), and is analogous to Lactate Turn Point 1 (LTP_1). The point *C* on the *HR/BL* curve which corresponds to a BL of approximately 4mM, and is analogous to LTP_2. The point *B* on the *HR/BL* curve, which corresponds to the load (16.32 ± 0.49 km h^{-1}) at which the moderate increase turns into a more pronounced increase in BL. This point has not been previously recognized in literature. We speculate this point represents attenuation of left ventricular ejection fraction (LVEF) increase, accompained by the decrease in diastolic time duration during incremental exercise testing. Proposed mathematical approach allows precise determination of lactate turnpoints during incremental exercise testing.

Keywords: aerobic threshold, anaerobic threshold, lactate turnpoints, heart rate, blood lactate curves, incremental exercise testing

It is well known that heart rate (HR) progressively increases during incremental exercise tests, but the question is: what is the shape of this HR curve? The first observations about nonlinear coupling of HR response to incremental workloads were made by Brooke et al. (5, 6), suggesting an S-shape HR curve during an incremental exercise test. Many authors (8, 13) have confirmed those findings.

Despite that, Conconi and coworkers (11) proposed a non-invasive method for the determination of, what they have defined as, the anaerobic threshold (AT) during incremental exercise tests. This original method is based on a specific relationship between HR and increasing load during incremental exercise tests. They claimed that the linear increase of heart rate is interrupted at the point near maximal exercise intensity. This point has been called the "heart rate deflection point" or HRDP, and it occurs almost simultaneously with the blood lactate reaching AT, according to these authors.

Meanwhile, various mathematical models have also been introduced in order to allow a more objective assessment of the HR curve in incremental exercise tests. Logistic function (22) and a third order curvilinear regression equation (18) have been used to assess the HR curve. In addition, regression techniques, such as simple linear regression (19, 21) and 2-compartment linear regression (7, 27), together with monosegmental exponential and

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