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Original article

Calculating lactate anaerobic thresholds in sports involving different endurance preparation

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Abstract

The aim of this study was to establish the degree of similarity of exercise intensity values at the anaerobic threshold (AT) provided by five methods of lactate curve analysis, i.e., LT_{AT}, LT_{loglog}, 1 mmol AT, 4 mmol AT, and D-max. The pattern of similarities and differences was sought in athletes with varying levels of experience and sports skills, representing two disciplines with different prevailing types of power output during competition: on-road cycling (aerobic metabolism) and ice-hockey (anaerobic metabolism).

All groups of athletes tested [Group 1: on-road cyclists ($n = 19$) at international sporting level (participants of the Olympic Games and World Championships); Group 2: on-road cyclists ($n = 20$) at national sporting level; Group 3: ice-hockey players ($n = 24$) at international sporting level (Polish National Team); and Group 4: ice-hockey players ($n = 22$) at international sporting level (Polish National Team U-20)] performed an incremental exercise.

The greatest power values at the anaerobic threshold (PAT) were provided by the LT_{AT} (221.93 ± 34.5 W) and 4 mmol AT (226.38 ± 32.33 W) methods, whereas the lowest were provided by the LT_{loglog} (190.71 ± 25.92 W) method. The PAT produced by the LT_{loglog} method was statistically significantly lower ($p \leq 0.001$) than the values provided by LT_{AT}, 4 mmol AT, and D_{max}. The PAT levels were found to be statistically significantly different for power values determined using the 4 mmol AT and those produced by the 1 mmol AT ($p \leq 0.001$) and D-max ($p \leq 0.01$) methods. As shown by the analyses, PAT values vary in the international-level on-road cyclists depending on the method of lactate curve analysis applied.

Keywords: Anaerobic threshold; Endurance training; Lactate threshold

Introduction

Aerobic−anaerobic thresholds sought using methods that analyze changes in lactate concentration kinetics during incremental exercise are commonly used in athletic training as indicators of an athlete's endurance, preparedness, and training load parameters.[39] The point where a lactate curve shows characteristic changes is known as an anaerobic threshold (AT), the lactate threshold (LT), the onset of blood lactate accumulation (OBLA), a maximal lactate steady state (MLSS), and a 4 mmol critical threshold.[61] As an indicator of changes in endurance, the anaerobic threshold parameters sought by studies mostly concentrate on endurance athletes, such as cyclists,[31,37] long-distance runners,[44,51] triathletes,[30] cross-country ski runners,[24,45,55] canoeing[43] and rowing.[5,10] The level and dynamics of changes in the anaerobic threshold that take place during training have also been studied in many other disciplines, such as football,[23] basketball,[14,29] ice-hockey[19] and judo.[57] Being able to determine

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exactly what intensity of an athlete's exercise involves mainly anaerobic metabolism is a very important element of planning athletic training as well as being crucial for selecting training volume and intensity.[8] The basic method that seeks the anaerobic threshold (AT) level based on the kinetics of blood lactate concentration (LA) during incremental exercise is an exponential method (LA_{AT}) that was described by Lundberg et al (1986)[46] and approved for incremental exercise tests by Hughson et al (1987).[36] The method assumes that a set of LA values can be described with respect to exercise intensity using an exponential model (a continuous method). The AT is determined as a projection of the point where the exponential (lactate) curve intersects its tangent drawn at 45° onto intensity axis. Beaver et al (1985)[4] showed that taking the logarithms of load and LA values offers a more precise identification of exercise intensity at the AT. Known as LT_{loglog}, their method finds the AT value where the LA points start deviating upwards from the values lying along a straight regression line representing changes taking place under exercise intensity below the AT. Where this straight line intersects the regression line for quickly increasing values is recorded as the AT. The practical application of both these methods in training practice was described by Saar (1986)[56] based on tests involving ski runners. The relationship between a nonlinear LA growth and exercise intensity was noted by Ivy et al (1980),[38] who determined the limit values of exercise intensity on this basis. This concept of exercise intensity assessment was used by Coyle et al (1983),[21] who assumed that the exercise intensity at the AT level made lactate concentration increase by 1 mmol l^{-1}. This method was named 1 mmol AT. Karlson and Jacobs (1982)[42] assumed as a standard that 4 mmol l^{-1} corresponds to exercise intensity at the lactate threshold. Lactate curve analyses performed by Heck et al (1985)[34] showed that it was rational to assume that a value making lactate concentration grow in excess of 4 mmol l^{-1} (4 mmol AT) could be taken as exercise intensity at the AT. Cheng et al (1992)[15] proposed a different approach to lactate curve analysis aimed at determining the AT threshold (D-max). This method assumes that exercise intensity at the AT is given by a projection on the intensity axis drawn from a point situated on the section linking the extreme points of the lactate curve on the most distant point from that curve.

Each of the above methods of lactate curve analysis requires a graded incremental exercise test[27,49] to assess changes in aerobic endurance performance capacity.[25] The similarity of the requirements applying to the exercise test procedures in all these methods enables comparisons of exercise intensity parameters at the AT level. The methods used for determining the AT were compared in the studies by Brooks (1985), Heck et al (1985), Lundberg et al (1986), Svedahl and MacIntosh (2003), and McGehee et al (2005).[11,34,46,48,61] There are no studies, however, dealing with the compatibility of methods when athletes representing the same sports discipline but with different training experience and sports skills are tested. Comparative analyses of a single method using lactate kinetics to determine the AT in athletes in disciplines varying in terms of the type of effort (endurance sports, speed-endurance sports) are not available either.

This study aimed to establish the degree of similarity of exercise intensity values at the AT provided by five methods of lactate curve analysis: LT_{AT}[36,46]; LT_{loglog}[4]; 1 mmol AT[20]; 4 mmol AT[34]; and D-max.[15] The pattern of similarities and differences was sought in athletes with varying levels of experience and sports skills, representing two disciplines with different prevailing types of power output during competition: on-road cycling (aerobic metabolism) and ice-hockey (anaerobic metabolism).

Methods

Participants

Four groups of male athletes with different sports skills and training experience as well as athletic specialization (on-road cyclists and ice hockey players) were selected. Group 1 consisted of on-road cyclists ($n = 19$) at international sporting level (participants of the Olympic Games and World Championships), with a mean ± standard deviation (SD) age of 24.9 (±4.1) years, height of 1.78 (±0.42) m, body mass of 67.1 (±2.2) kg, body fat 8.3% (±2.3%), maximal oxygen uptake of 78.2 (±3.2) mL kg^{-1} min^{-1}, training experience 13 (±1.5) years. Group 2 were on-road cyclists ($n = 20$) at national sporting level. These men had a mean (±SD) age of 19.8 (±0.7) years, height 1.77 (±0.37) m, body mass 58.6 (±3.1) kg, body fat 8.9% (±1.9%), maximal oxygen uptake 67.2 (±3.2) ml kg^{-1} min^{-1}, and training experience of 8.6 (±1.8) years. Group 3 consisted of ice-hockey players ($n = 24$) at international sporting level (Polish National Team), with a mean (±SD) age of 25.8 (±3.6) years, body mass 84.8 (±5.1) kg, height 181.9 (±7.7) cm, body fat 17.3% (4.4%), maximal oxygen uptake 56.2 (±4.2) ml kg^{-1} min^{-1}, and training experience of 14–18 years. Group 4 were ice-hockey players ($n = 22$) at international sporting level (Polish National Team U-20), with a mean (±SD) age of 19.4 (±0.7) years, body mass 79.8 (±4.2) kg, height 184.9 (±4.4) cm, body fat 15.4% (3.3%), maximal oxygen uptake 58.3 (4.1) ml kg^{-1} min^{-1}, and training experience of 8–10 years. After being informed about the study and test procedures, and any possible risks and discomfort that might ensue, their written informed consent to participate was obtained in accordance with the Helsinki Declaration (2000).[66]

Research method

All groups of athletes tested performed an incremental exercise.[60] The on-road cyclists (Group 1 and Group 2) and the ice-hockey players (Group 3 and Group 4) exercised on the exercise intensity values at the AT. The initial load of 1 W kg^{-1} b.m. grew incrementally by 0.5 W kg^{-1} b.m every 3 minutes. During the final 30 seconds of each step, a sample of 20 μL of arterial blood was taken from the individual's ear lobe so that lactate concentration could be established. The lactate concentration values were recorded using reagents