Evaluating the effects of anaerobic threshold on heart rate work rate relationships during incremental exercise in healthy male subjects

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Accepted 25 February, 2020

ABSTRACT

The purpose of the present study was to determine the effectiveness of work rate to heart rate ratio at the estimated anaerobic threshold (A\text{T}). Thirty male subjects performed an incremental exercise test (15 W/min) until the limit of tolerance was reached. Ventilatory and gas exchange parameters were evaluated breath-by-breath and the heart rate was recorded. A\text{T} was estimated from the work rate heart rate ratio and compared with the V-slope method. A deviation from linearity in heart rate was observed only in 4 subjects (13%) and 3 of them (10%) associated with A\text{T}. All other 26 subjects showed linear increase in heart rate to work rate relationships (87%). The O\text{2} uptake at the estimated A\text{T} using V-slope break point was found to be 1.95 ± 0.2 L/min (65% of maximal O\text{2} uptake). Absence of a break point in heart rate work rate relationship (87%) and an extremely low percentage of association in A\text{T} estimation between the Conconi and V-slope methods (10%) may reduce the reliability of the Conconi test. Thus, caution should be taken by investigators using this technique, especially when making important decisions for patients and sports training.

Keywords: Anaerobic threshold, heart rate, Conconi method, exercise, V-slope.

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INTRODUCTION

Cardiopulmonary function test has been used to evaluate capacity of the body’s organs and systems fitness levels (Wasserman et al., 2012). Evaluation of fitness status of individual, at rest and also during various type of muscular exercise performance, is one of the important issues that requires to be clarified in clinical medicine and sports sciences (Palange et al., 2007; Stringer, 2010).

Anaerobic threshold (A\text{T}), which describes onset of systematic increase in blood lactate concentration, has been a widely used criterion for assessing cardiopulmonary fitness during muscular exercise performance (Wasserman et al., 2012). A\text{T} provides important information about the status of physiological system of the body involved in the performance of physical activity (Ugras and Ozcelik, 2019). Thus A\text{T} becomes one of the important determinants of an individual’s functional aerobic capacity (Ozcelik et al., 2015). Invasive A\text{T} determination requires continuous blood lactate measurements during exercise (Solberg et al., 2005). However, non-invasive methods are based on the analysis of variation in the response of ventilatory and pulmonary gas exchange parameter or metabolic variables (Beaver et al., 1986; Ozcelik et al., 2004; Wasserman et al., 2012).

Since its first introduction by Wasserman and Mcilroy (1964), interest in the determination of A\text{T} has increased because of the inclusion of qualitative and systematic research in health studies for different purposes, including establishing an optimum training work rate (Ozcelik et al. 2015), determining aerobic fitness (Spurway, 1992), assessing the efficacy of treatment (Amonette and Mossberg, 2013), classifying the risk of early death (Gitt et al., 2002), improving cognitive functions (Cordova et al., 2009), and even determining a
The heart rate response to the progressively increasing work rate has been used for non-invasive A\textsubscript{T} estimation (Conconi et al., 1982). Thus a deflection point in heart rate work rate relationships during an incremental exercise has been suggested as an indicator of onset of anaerobic metabolism (Conconi et al., 1982; Kjertakov et al., 2016; Sant’Ana et al., 2019). However, heart rate work rate relationships and its effectiveness on A\textsubscript{T} estimation has been questioned in many studies (Ozcelik and Kelestimur, 2004; Bourgeois et al., 2004).

In the present study to evaluate the validity, efficiency and reliability of A\textsubscript{T} estimation using heart rate work rate relationships, it has been compared with the other conventional non-invasive methods based on ventilatory and pulmonary gas exchange parameters.

**MATERIALS AND METHODS**

**Subjects**

Total of 55 male subjects (mean ± SD, age: 23.1 ± 4 years; height: 178 ± 6 cm; weight: 77.8 ± 17 kg, body mass index: 24.4 ± 4.9 kg/m\(^2\)) were participated to this study. The study protocols were approved local ethical committee. Signed informed consents were taken from all subjects before participating in the study. The study protocols and any risk concerning the study protocol have been given to the subjects.

The subjects including criteria’s are: a) age should be 18 to 30 years; b) they should be free of any diseases including, skeletal, cardiac respiratory, metabolic, etc; c) they should be taking no medicine or drug, alcohol or smoking.

The subjects body weight, height and compositions were measured using foot to foot bioelectrical impedance analysis before test (Tanita, TBF 300 M, Japan) (Kaya and Ozcelik, 2009). The exercise tests were performed in a climatically controlled laboratory where temperature was kept at 18 to 22°C. The subjects were familiarized with the laboratory environment. Each subject was instructed to avoid any heavy physical activity at least before 24 h of testing and eat a light meal 2 h before testing.

The incremental exercise test was performed on an electromagnetically braked cycle ergometer (VIA SprintTM150/200P) that was completely adjustable to the physical dimensions of the cyclist. The exercise test started with a work load 20 W (at 60 rpm) for 4 min as a warm up period. Then the work load increased by a work load controller as 15 W/min until the subjects could not continue to cycling (Whipp et al., 1981). At this point, the work load decreased to 20 W again for 4 min as a recovery period. During warm up period of the exercise test, the subject’s ventilatory response was controlled for excitability related hyperventilation that cause reduced body CO\textsubscript{2} stores and result pseudo-threshold phenomenon (Ozcelik et al., 1999).

During the incremental exercise test, ventilator and pulmonary gas exchange parameters were estimated breath-by-breath. Ventilatory parameters were evaluated using a light weight, low resistance turbine volume transducer (TripleV-Volume Sensor) and gas exchange parameters were evaluated using a gas analyser system (MasterScreen CPX, Germany). The system was calibrated for temperature, barometric pressure, O\textsubscript{2} and CO\textsubscript{2} concentrations according to the manufacturer’s specifications before each test. Cardiac parameters (including heart rate, ST, T and QT) were followed continuously using a 12 lead ECG. Heart rate was recorded beat-by-beat throughout the study.

During incremental exercise test, estimation of A\textsubscript{T} was performed using V-Slope method based on determination of relationships between CO\textsubscript{2} output (VCO\textsubscript{2}) O\textsubscript{2} uptake (VO\textsubscript{2}) ratio (Beaver et al., 1986). During an incremental exercise test, initially VCO\textsubscript{2} increases linearly with VO\textsubscript{2} reflecting aerobic metabolic demands. However, VCO\textsubscript{2} increases out of proportion to VO\textsubscript{2}, due to the non-metabolic CO\textsubscript{2} comes from HCO\textsubscript{3}- Lactic Acid reaction when the work load intervene a specific point reflects anaerobic metabolism and called as A\textsubscript{T}. In addition, estimation of A\textsubscript{T} was supported form other non-invasive methods: the systematic increase in end tidal PO\textsubscript{2} (PETO\textsubscript{2}) without decrease end tidal PCO\textsubscript{2} (PETCO\textsubscript{2}) (Beaver et al., 1986; Ozcelik and Kelestimur, 2004; Algul et al., 2017a) and also systematic increase in ventilatory equivalent for oxygen (V\textsubscript{E}/VO\textsubscript{2}) without increase in ventilatory equivalent for carbon dioxide (V\textsubscript{E}/VCO\textsubscript{2}) (Beaver et al., 1986; Ozcelik and Kelestimur, 2004; Algul et al., 2017b).

A\textsubscript{T} was estimated from heart rate versus work rate plot and break point in this relationship has been considered as AT (Conconi et al., 1982; Ozcelik et al., 2004)

**Statistical analysis**

Values were expressed as mean (±SD). A paired t- test was used to evaluate values observed from the V-slope method and the heart rate versus work rate plot. The heart rate work rate relationships were evaluated using a linear regression analysis. Significance was set at p < 0.05 for all statistical analyses.

**RESULTS**

Maximal exercise capacity (W\textsubscript{max}) and work rate at the A\textsubscript{T} were found to be 198±33 W and 120±20 W, respectively. The A\textsubscript{T} was found to be 60.6% of W\textsubscript{max}. The mean (±SD) values of heart beat response to the incremental exercise performance are given in Figure 1.

The subject’s fitness status as determined by maximal
exercise work production capacity for each kg of body weight was $2.656 \pm 0.6$ W/dk/kg (ranged min 1.102 W/dk/kg to max 3.812 W/dk/kg). The work production capacity for each kg of body weight at the AT was $1.591 \pm 0.3$ W/dk/kg (ranged min 0.669 W/dk/kg to max 2.199 W/dk/kg).

Each heart beat for work rate production ratio during incremental exercise test was found to be $2.146 \pm 0.3$ beat/W. This ratio was found to be $2.407 \pm 0.5$ beta/W in aerobic region and $2.039 \pm 0.6$ beat/W in anaerobic region of incremental exercise test ($p < 0.0001$).

A linear increase in heart rate response to the incremental exercise test is presented in Figure 2. Heart rate work rate relationships showed a linear increase in 43 subjects out of 55 (78%) (Figure 3). The break point in heart rate to work rate relationships was observed in only 12 subjects (22%). The break point in heart rate work rate relationships did not associated with AT estimated V-slope and it occurred between the AT and W$_{max}$.

**DISCUSSION**

In the present study, heart rate and work rate relationship were evaluated during a progressively increasing exercise test with subjects’ different fitness status (Ozcelik et al., 2004).

In this study, there was no association between AT estimation using V-slope and conventional methods and heart rate break point. A break point in heart rate work rate relationships that occurred in only 12 subjects (22%) and occurred systematically above AT and close to W$_{max}$. Most subjects showed linear increase in heart rate during incremental exercise test (Figure 2 and 3). This finding is associated with some previous publications (Algul et al., 2015; Ozcelik and kelestimur, 2004; Bourgois et al., 2004). However, in a study 86% of break point in heart rate work rate relationships has been reported (Hofmann et al., 1997).
This heart rate work rate based method has been used for training in many sports activity (Ciric et al., 2012; Alberton et al., 2013).

There is no satisfactory explanation concerning physiological mechanisms behind the heart rate work rate break point incident. It has been proposed that deflection in heart rate during exercise is caused by activation of the anaerobic lactic acid mechanisms of ATP production (Conconi et al., 1996). However, this is not supported by finding of present study.

However, there are some explanations with break point including myocardial function catecholamine effects, sympathetic system activity, potassium levels (Bodner and Rhodes, 2000) The heart rate-work rate relationships under the acute hypoxic conditions show no significant differences despite the marked change in metabolism, exercise performance and AT (Ozcelik and Kelestimur, 2004).

The lack of a break point in heart rate and work rate relationship and the extremely low percent of heart rate break point may reduce the reliability of the Conconi test. As a conclusion, the results of present study reveal that heart rate work rate relationships may not be applied for routine functional capacity evaluation. Therefore, caution should be taken by investigators, especially those making important decisions for patients and sports training.

REFERENCES


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