African Educational Research Journal
Vol. 8(1), pp. 36-40, February 2020
DOI: 10.30918/AERJ.81.20.007
ISSN: 2354-2160
Full Length Research Paper

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

Çağrı Özdenk

School of Physical Education and Sports, University of Çoruh, Artvin, Turkey.

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_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_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_T. All other 26 subjects showed linear increase in heart rate to work rate relationships (87%). The O_2 uptake at the estimated A_T using V-slope break point was found to be 1.95 ± 0.2 L/min (65% of maximal O_2 uptake). Absence of a break point in heart rate work rate relationship (87%) and an extremely low percentage of association in A_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.

E-mail: ozdenkcagri@hotmail.com. Tel: +90 553 535 36 42. Fax: +90 466 215 10 55.

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_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_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_T becomes one of the important determinants of an individual's functional aerobic capacity (Ozcelik et al., 2015). Invasive A_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_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 patient's suitability for major surgery (West et al., 2016).

The heart rate response to the progressively increasing work rate has been used for non-invasive A_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_T estimation has be questioned in many studies (Ozcelik and Kelestimur, 2004; Bourgois et al., 2004).

In the present study to evaluate the validity, efficiency and reliability of A_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 (VIAsprintTM150/200P) 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_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_2 and CO_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_T was performed using V-Slope method based on determination of relationships between CO_2 output (VCO_2) O_2 uptake (VO_2) ratio (Beaver et al., 1986). During an incremental exercise test, initially VCO_2 increases linearly with VO_2 reflecting aerobic metabolic demands. However, VCO_2 increases out of proportion to VO_2, due to the non-metabolic CO_2 comes from HCO_3- Lactic Acid reaction when the work load intervene a specific point reflects anaerobic metabolism and called as A_T. In addition, estimation of A_T was supported form other non-invasive methods: the systematic increase in end tidal PO_2 ($PETO_2$) without decrease end tidal PCO_2 ($PETCO_2$) (Beaver et al., 1986; Ozcelik and Kelestimur, 2004; Algul et al., 2017a) and also systematic increase in ventilatory equivalent for oxygen (V_E/VO_2) without increase in ventilatory equivalent for carbon dioxide (V_E/VCO_2) (Beaver et al., 1986; Ozcelik and Kelestimur, 2004; Algul et al., 2017b).

A_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_{max}) and work rate at the A_T were found to be 198±33 W and 120±20 W, respectively. The A_T was found to be 60.6% of W_{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

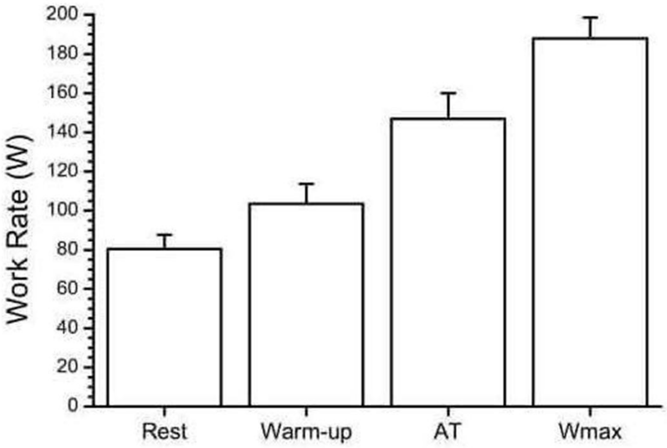

Figure 1. Mean (±SD) values of heart rate response to the incremental exercise test at rest, at warm-up period at anaerobic threshold and at maximal exercise performance (n=55).

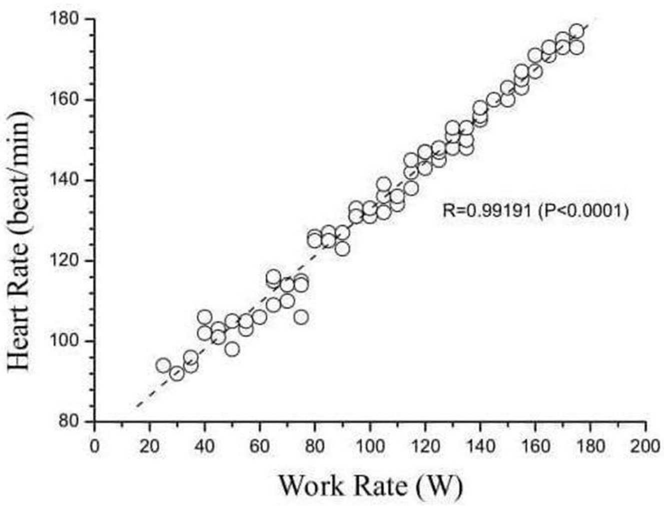

Figure 2. Representative plots of heart rate to work rate relationships during an incremental exercise test.

exercise work production capacity for each kg of body weight was 2.656 ± 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±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 ± 0.3 beat/W. This ratio was found to be 2.407 ± 0.5 beta/W in aerobic region and 2.039 ± 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

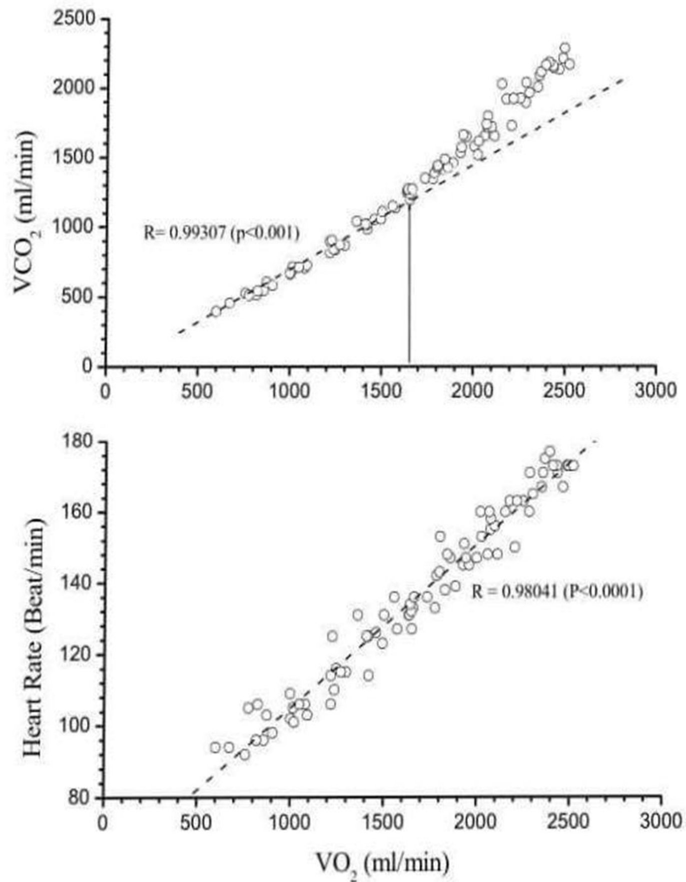

Figure 3. Representative plots of V-slope method (a person sample data) (upper graphs) and linear increase of heart rate to O_2 uptake (lower graph) during an incremental exercise test.

12 subjects (22%). The break point in heart rate work rate relationships did not associated with A_T estimated V-slope and it occurred between the A_T 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 A_T 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 A_T 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

Alberton, C. L., Kanitz, A. C., Pinto, S. S., Antunes, A. H., Finatto, P., Cadore, E. L., and Kruel, L. F. (**2013**). Determining the anaerobic threshold in water aerobic exercises: a comparison between the heart rate deflection point and the ventilatory method. Journal of Sports Medicine and Physical Fitness, 53: 358-367.

Algul, S., Ozcelik, O., and Yilmaz, B. (**2017a**). Evaluation of relationship between aerobic fitness level and range of isocapnic buffering periods during incremental exercise test. Cellular and Molecular Biology (Noisy-le-grand), 63(3): 78-82.

Algul, S., Serhatlioglu, I., and Ozcelik, O. (**2015**). The work rate divided to heart rate ratio during an incremental exercise test is an effective method for estimation of anaerobic threshold. Firat Medical Journal, 29(3): 117-121.

Algul, S., Ugur, F. A., Ayar, A., and Ozcelik, O. (**2017b**). Comparative determination of ventilator efficiency from constant load and incremental exercise testing. Cellular and Molecular Biology (Noisy-le-grand), 63(7): 26-30.

Amonette, W. E., and **Mossberg**, K. A. (**2013**). Ventilatory anaerobic thresholds of individuals recovering from traumatic brain injury compared with non-injured controls. Journal of Head Trauma Rehabilitation, 28: 13-20.

Beaver, W. L., Wasserman, K., and Whipp, B. J. (**1986**). A new method for detecting anaerobic threshold by gas exchange. Journal of Applied Physiology, 60(6): 2020-2027.

Bodner, M. E., and **Rhodes**, E. C. (**2000**). A review of the concept of the heart rate deflection point. Sports Medicine, 1(30): 31-46.

Bourgois, J., Coorevits, P., Danneels, L., Witrouw, E., Cambier, D., and Vrijenjs, J. (**2004**). Validity of the heart rate deflection point as a predictor of lactate threshold concepts during cycling. Journal of Strength and Conditioning Research,18: 498-503.

Ciric, I. M., Stojiljkovic, S., Bjelakovic, L., Nikolic, M. D., Djurdjevic, S. M., and Pirsl, D. S. (**2012**). Difference in the heart rate and the blood lactate level in football and hanball female players during the Conconi test. Healthmed, 6: 2004-2009.

Conconi, F., Ferrari, M., Ziglio, P. G., Droghetti, P., and Codeca, L. (**1982**). Determination of the anaerobic threshold by a non-invasive field test in runners. Journal of Applied Physiology, 52: 869-873.

Cordova, C., Silva, V. C., Moraes, C. F., Simoes, H. G., Nobrega, O. T. (**2009**). Acute exercise performed close to the anaerobic threshold improves cognitive performance in elderly females. Brazilian Journal of Medical and Biological Research, 42: 458-464.

Gitt, A. K., Wasserman, K., Kilkowski, C., Kleemaan, T., Kilkowski, A., Bangert, M., Schneider, S., Schwarz, A., and Senges, J. (**2002**). Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for high risk of early death. Circulation, 106: 3079-3084.

Hofmann, P., Pokan, R., Von Duvillard, S. P., Seibert, F. J., Zweiker, R., and Schmid, P. (**1997**). Heart rate performance curve during incremental cycle ergometer exercise in healthy young male subjects. Medicine & Science in Sports & Exercise, 29(6): 762-768.

Kaya, H., and **Ozcelik**, O. (**2009**). Comparison of effectiveness of body mass index and bioelectric impedance analysis methods on body composition in subjects with different ages and sex. Sağlık Bilimleri Tip Dergisi, Fırat Üniversitesi, 23(1): 1-5.

Kjertakov, M., Dalip, M., Hristovski, R., and Epstein, Y. (**2016**). Prediction of lactate threshold using the modified Conconi test in distance runners. Physiology International, 103(2): 262-270.

Ozcelik, O., and **Kelestimur**, H. (**2004**). Effects of acute hypoxia on the determination of anaerobic threshold using the heart rate-work rate relationships during incremental exercise tests. Physiology Research, 53:45-52.

Ozcelik, O., and **Kelestimur**, H. (**2004**). Effects of acute hypoxia on the estimation of lactate threshold from ventilatory gas exchange indices during an incremental exercise test. Physiology Research, 53(6): 653-659.

Ozcelik, O., Aslan, M., Ayar, A., and Kelestimur, H. (**2004**). Effects of body mass index on maximal work production capacity and aerobic fitness during incremental exercise. Physiology Research, 53(2): 165-170.

Ozcelik, O., Ozkan, Y., Algul, S., and Colak, R. (**2015**). Beneficial effects of training at the anaerobic threshold in addition to pharmacotherapy on weight loss, body composition, and exercise performance in women with obesity. Patient Preference and Adherence, 9: 999-1004.

Ozcelik, O., Ward, S. A., and Whipp, B. J. (**1999**). Effect of altered body CO_2 stores on pulmonary gas exchange dynamics during incremental exercise in humans. Experimental Physiology, 84: 999-1011.

Palange, P., Ward, S. A., Carlsen, K. H., Casaburi, R., Gallagher, C. G., Gosselink, R., O'Donnell, D. E., Puente-Maestu, L., Schols, A. M., Singh, S., and Whipp, B. J. (**2007**). Recommendations on the use of exercise testing in clinical practice. European Respiratory Journal, 29: 185-209.

Sant'Ana, J., Franchini, E., Murias, J., and Diefenthaeler, F. (**2019**). Validity of a taekwondo specific test to measure VO_2 peak and the heart rate deflection point. Journal of Strength and Conditioning Research, 33(9): 2523-2529.

Solberg, G., Robstad, B., Skjønsberg, O. H., and Borchsenius, F. (**2005**). Respiratory gas exchange indices for estimating the anaerobic threshold. Journal of Sports Science and Medicine, 4(1): 29-36.

Spurway, N. C. (**1992**). Aerobic exercise, anaerobic exercise and the lactate threshold. British Medical Bulletin, 48(3): 569-591.

Stringer, W. W. (**2010**). Cardiopulmonary exercise testing: current applications. Expert Review of Respiratory Medicine, 4(2): 179-188.

Ugras, S., and **Ozcelik**, O. (**2019**). Eşik altı yoğunluğundaki egzersizin genç erkeklerde vücut yağ ve karbonhidrat yakım miktari ve oranı üzerine olan etkileri. Genel Tip Dergisi, 29(2): 48-54.

Wasserman, K., and **Mcilroy**, M. B. (**1964**). Detecting the threshold of anaerobic metabolism in cardiac patients during exercise. American Journal of Cardiology, 14:844-852.

Wasserman, K., Hansen, J. E., Sue, D. Y., Stringer, W. W., Sietsema, K. E., and Sun, X. G. (**2012**). Principles of exercise testing and interpretation: including pathophysiology and clinical applications. Fifth Ed. Philadelphia: Lippincott Williams & Wilkins.

West, M. A., Asher, R., Browning, M., Minto, G., Swart, M., Richardson, K., McGarrity, L., Jack, S., and Grocott, M. P. (**2016**). Validation of preoperative cardiopulmonary exercise testing-derived variables to predict in-hospital morbidity after major colorectal surgery. British Journal of Surgery, 103(6): 744-752.

Whipp, B. J., Davis, J. A., Tores, F., and Wasserman, K. (**1981**). A test to determine parameters of aerobic function during exercise. Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology, 50(1): 217-221.

Citation: Özdenk, C. (2020). Evaluating the effects of anaerobic threshold on heart rate work rate relationships during incremental exercise in healthy male subjects. African Educational Research Journal, 8(1): 36-40.