ARAŞTIRMA

F.Ü.Sağ.Bil.Tıp Derg.
2015; 29 (3): 117 - 121
http://www.fusabil.org

The Work Rate Divided to Heart Rate Ratio during an Incremental Exercise Test is an Effective Method for Estimation of Anaerobic Threshold

Sermin ALGÜL[1]
İhsan SERHATLIOĞLU[2]
Oğuz ÖZÇELİK[1]

[1]Fırat Üniversitesi,
Tıp Fakültesi,
Fizyoloji Anabilim Dalı,
Elazığ, TÜRKİYE

[2]Fırat Üniversitesi,
Tıp Fakültesi,
Biyofizik Anabilim Dalı,
Elazığ, TÜRKİYE

Objective: The effectiveness of work rate divided to heart rate ratio on anaerobic threshold (AT) estimation was evaluated.

Material and Method: Twenty five male subjects performed an incremental exercise test (15 W/min) until the limit of tolerance. During exercise, respiratory and gas exchange parameters were evaluated breath-by-breath. The heart rate was recorded as beat-by-beat. AT estimated from the work rate divided to heart rate ratio, heart rate versus work rate plot (Conconi method) and compared with the V-slope method.

Results: A deviation from linearity in heart rate was observed only in 6 subjects. Other 19 subjects have linear increase in heart rate to work rate relationships. The work rate divided to heart rate ratio showed a clear break point in all subjects and closely associated with the V-slope break point: 1.91±0.04 L/min vs 1.89±0.03 L/min. Absent of a break point in heart rate work rate relationship (76%) and an extremely low percent of association in AT estimation between Conconi and V-slope method (%16) may reduce reliability of Conconi test.

Conclusion: Thus, caution should be taken by investigators especially making important decision for patients and sports training. However, work rate to heart rate ratio could provide easy and reliable AT estimation.

Key Words: *Anaerobic threshold, heart rate, conconi method, exercise, V-slope*

Şiddeti Düzenli olarak Artan Yüke Karşı Yapılan Egzersiz Sırasında İş Gücünün Kalp Atım Oranı Anaerobik Eşik Hesaplanmasında Etkin bir Yöntemdir

Amaç: Egzersiz sırasında iş gücünün kalp atım hızına oranının anaerobik eşiğin (AE) hesaplanmasında etkinliliği araştırıldı.

Gereç ve Yöntem: Yirmi beş erkek denek şiddeti düzenli olarak artan yüke karşı yapılan egzersiz (15 W/dak) testine yorulana kadar devam ettirdiler. Egzersiz sırasında, solunum ve gaz değişim parametreleri solunumdan solunuma hesaplanmıştır. Kalp atım hızı her atımdan atıma kaydedildi. AE iş gücü ile kalp atım oranı, iş gücünün kalp atım hızı ilişkisi (Conconi metodu) ve V-slope metodu ile hesaplandı.

Bulgular: Kalp atım oranındaki kırılma sadece 6 denekte gözlendi. Diğer 19 denek kalp atım hızı iş gücü ilişkisinde lineer bir artış gösterdi. İş gücünün kalp atım hızı oranında tüm deneklerde gözlenen kırılma noktası V-slope kırılma noktası ile benzerlik gösterdi: 1.91±0.04 L/dk, ve 1.89±0.03 L/dk. Kırılma noktasının eksikliği (%76) ve çok düşük oranda eşleşen Conconi ve V-slope AE tespiti (%16), Conconi testinin güvenilirliğini azaltmaktadır.

Sonuç: Araştırmacılar hasta ve sporcular için özellikle önemli kararlar verirken dikkat etmelidirler. Fakat iş gücünün kalp atım hızı oranı kolayca güvenilir bir yöntem olarak AE hesaplanmasını sağlayabilir.

Anahtar Kelimeler: *Anaerobik eşik, kalp atım hızı, conconi metod, egzersiz, V-slope*

**Geliş Tarihi : **08.01.2016
**Kabul Tarihi : **11.02.2016

Yazışma Adresi
Correspondence

İhsan SERHATLIOĞLU
Fırat Üniversitesi,
Tıp Fakültesi,
Biyofizik Anabilim Dalı,
Elazığ–TÜRKİYE

iserhatlioglu@firat.edu.tr

Introduction

Cardiopulmonary fitness is a crucially important indicator of the body's organs and system functions. Anaerobic threshold (AT) reflects the transition point from aerobic to anaerobic metabolism during muscular exercise performance. It has been widely used criteria for assessing cardiopulmonary fitness (1). In recent years, the popularity of AT concept has been increased and used for different purposes, including establishing an optimum training work rate (2), determining aerobic fitness (3), assessing the efficacy of treatment (4), improving cognitive functions (5), and even a patient's suitability for major surgery (6).

In the last few decades, several invasive and non-invasive methods have been introduced to determine or estimate the AT. The most accurate and reliable method to determine AT is the direct testing of arterial blood lactate accumulation during incremental exercise test (7). However, this is not often applicable to most performers. The various non-invasive methods mainly based on metabolic and ventilatory gas exchange parameters, have been developed to estimate AT (1, 8, 9).

The V-slope method during incremental exercise has been shown as the most effective way to estimate AT non-invasively (8, 10, 11). This method based on detecting increased CO_2 output (VCO_2) as a function of O_2 uptake (VO_2) where extra CO_2 comes from lactate-bicarbonate buffer system during anaerobic metabolism (1, 8).

The techniques that based on respiratory and pulmonary gas exchange dynamics can be easily used in laboratory conditions, but may not be possible to apply some sports in the field. To solve this problem, heart rate-work rate relationships during exercise have been introduced as a non-invasive AT estimation outside the laboratory conditions (12).

It has been proposed that AT can be validly estimated simply by establishing the point at which heart rate linearity changes during exercise (12). However, there is no general agreement among the reports concerning the heart rate work rate-work rate deflection point (HRDP) and its relation with the actual AT (13-19). The vital disappointment in this technique is the observation of a linear increase in heart rate-work rate relationships during exercise performance in most subjects (13, 20, 21).

Due to wide application of AT in clinical and sports medicine for important decision, the methods used to estimate AT are of great importance. In this study, validity of AT estimation comparatively examined by using the HRDP and V-slope method. In addition, during an incremental exercise test, efficiency of the work rate divided to heart rate ratio on AT estimation was also examined.

Materials and Methods

Participants: Twenty-five male subjects (mean±SE, age: 20.2±0.3 yr; height: 180.8±1 cm; weight: 69.6±1 kg) were enrolled into this study after giving a written informed content. The University Ethics Committee approved the study protocol.

Before the test, the subject's height and body mass were measured (Tanita, TBF 300 M, Japan). The exercise tests were performed in a climatically controlled laboratory where temperature was kept at around 22ºC. The subjects familiarized with the laboratory environment and the experimental protocol that they would undergo. On the day of the test, they were instructed that taking no alcohol and stimulant drinks including coffee and tea, and had done no extenuating physical activity. All testing was performed between 08:00 and 10:00 AM.

General Procedures: All subjects performed an incremental exercise in the upright position on an electromagnetically braked ergometer (VIA sprint TM150/200P) that was completely adjustable to the physical dimensions of the subject. After a 4-min warm-up at 20 W, each subject performed a 1-min stage incremental exercise test to exhaustion with 15-W work increment (22). Then, the work load decreased to 20 W for 4 min as a recovery period. The pedalling frequency was between 50 and 70 rpm (average 60 rpm). Seat and handlebar heights were set for each subject.

During incremental exercise test, pulmonary gas exchange parameters were estimated breath-by-breath. Ventilatory parameters evaluated using a light weight low resistance turbine volume transducer (Triple V-Volume Sensor) and gas exchange parameters evaluated using a gas analyser system (MasterScreen CPX). The system was calibrated be for each test for temperature, barometric pressure, O_2 and CO_2 concentrations according to the manufacturer's specifications. Cardiac parameters (including heart rate, ST, T, QT) were followed continuously using 12 lead ECG. The heart rate was recorded as beat-by-beat throughout the study.

Estimation of AT: V-slope (8) other conventional methods, i.e. increase in end tidal PO_2 without decrease end tidal PCO_2; and increase in ventilatory equivalent for O_2 without increase in ventilatory equivalent for CO_2 (9), used in AT estimation.

The break point in heart rate versus work rate plot was used to estimate AT (12). In addition, the work rate divided to heart rate ratio was also used to estimate AT (Figure 1).

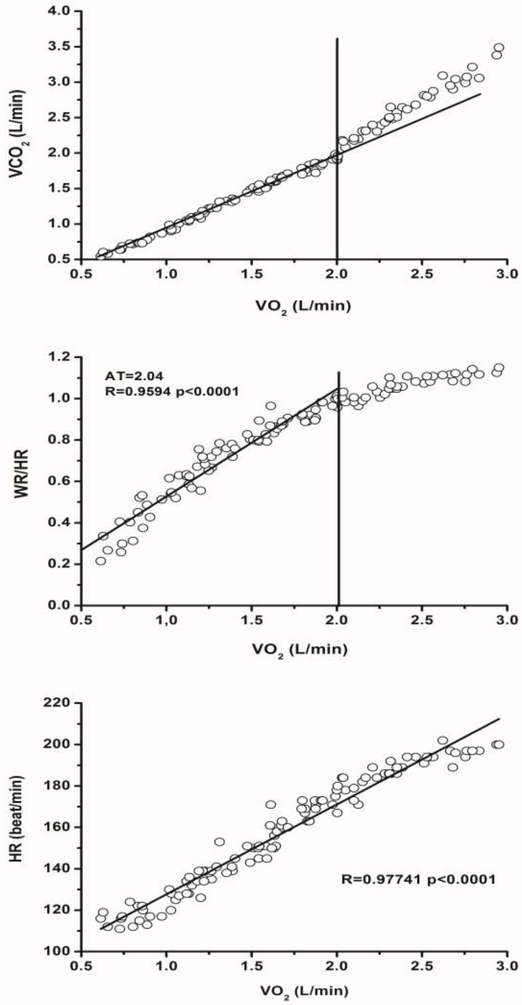

Figure 1. Representative plots of V-slope method (upper graphs), work rate to heart rate ratio (middle graph) and linear increase of heart rate to work rate relationships (lower graph) during incremental exercise

Statistical Analysis: Values were expressed as mean and standard error (±SE). A paired t-test was used to evaluate values observed from the V-slope method and the heart rate versus work rate plot. During exercise, estimated AT values obtained both the work rate divided to heart rate ratio and the V-slope relationship were evaluated using linear regression analysis. Significance was set at $P<0.05$ for all statistical analyses.

Results

Maximal exercise capacity (W_{max}), maximal VO_2 (VO_{2max}) and VO_2 for per kg body weight were found to be: 223±5 W, 2.97±0.06 L/min, and 43.2±1.2 mL/kg, respectively. The VO_2 at the AT was found to be 1.91±0.04 L/min.

During incremental exercise test, the heart rate-work rate relationship were observed in three different ways: linear increases in 19 subjects (76%), left side deflection in 4 subjects (16%) and right side deflection in 2 subjects (8%) (Table 1).

Table 1. Maximal exercise capacity (Wmax), work rate at the anaerobic threshold estimated from V-slope method and heart rate vs work rate relationship.

Subjects No	W_{AT} (V-Slope) (W)	W_{AT} HR vs WR (W)	Wmax (W)
1	155	Lineer	205
2	180	Lineer	230
3	155	Lineer	205
4	210	Lineer	265
5	150	Lineer	200
6	155	Lineer	210
7	170	Lineer	245
8	135	Lineer	195
9	150	Lineer	230
10	130	Lineer	215
11	170*	170W (LBP)	255
12	155*	155W (LBP)	260
13	140	Lineer	225
14	150*	150W (LBP)	260
15	130	165W (RB)	205
16	145	Lineer	235
17	125	Lineer	185
18	150	220W (RBP)	245
19	125	Linner	195
20	155	Lineer	230
21	120	Linner	205
22	130	Lineer	225
23	160	Lineer	260
24	120*	120W (LBP)	225
25	95	Lineer	175

LBP: Left break point; RBP: Right break point.
** AT was similar in both test*

Interestingly, the left deflection point in heart rate-work rate relationship associated with the AT estimated from the V-slope break point. However, the right side deflection point, did not associated with the AT estimated from the V-slope break point (Table 1). In these 2 subjects, the HRDP occurred above the AT (Table 1).

However, while the heart rate–work rate relationships occurred in linear manner, the work rate to heart rate ratio response to incremental exercise test showed a clear break point in all subjects (Figures 1) (Table). The break point obtained from the work rate to heart rate ratio was closely associated with the break point obtained in V-slope method ($R=0.889$, $P<0.0001$) (Figure 2).

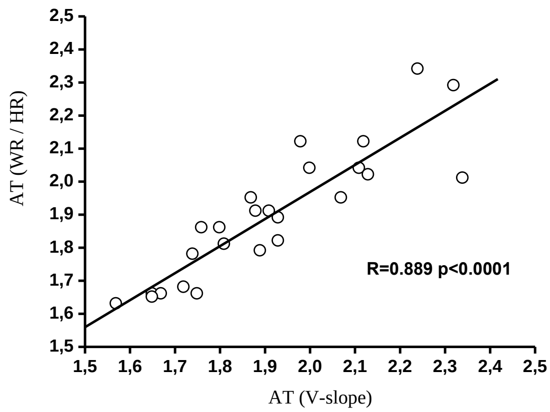

Figure 2. Linear regression analysis of AT estimated from using VO_2 at the WR/HR break point and VO_2 at the V-slope point (*n: 25*).

Discussion

In this study, we have attempted to clarify two important issues: evaluating the effectiveness of HRDP on valid AT estimation, and then examining the validity of work rate divided to heart rate ratio on AT estimation. Due to the easy and inexpensive non-invasive application, Conconi test becomes popular especially in training (12). Importantly, this method has been modified for several sports (18, 24-28). However, there are some serious questions regarding its accuracy (20, 21). In the literature, it has been reported that the Conconi method is not suitable to determine efficient exercise protocols in patients with cystic fibrosis and importantly training programs associated with Conconi method might even be harmful in these patients (29).

In consistent with results of several previous studies, we have observed linear increases heart rate in response to the incremental exercise test in extremely high number of subjects (19 out of 25 subjects, 76%) (20, 21, 29, 30). Naturally, it is not possible to estimate AT under the condition of linear increase in heart rate. An observation of high percentage (86%) break point in heart rate to work rate relationship was reported in young healthy male subjects (17).

The physiological mechanisms behind the 3 different heart rate response, (i.e. linear increase, left side deflection and right side deflection) during incremental exercise test have still not been fully explained. It seems logical to believe that the break point in heart rate work rate relation is related with the myocardial function of heart rather than the change in metabolism from aerobic to anaerobic. The observation of absent of break point and also dissociation of AT and HRDP in most subjects excludes the direct and strong relationship between anaerobic metabolic end productions and heart rate deflection. It has been proposed that deflection in heart rate during muscular exercise is caused by activation of the anaerobic lactic acid mechanisms of ATP production (31). There are various suggestions concerning the occurrence of HRDP, including increased potassium and catecholamine levels and their effects on myocardial functions (32,33), neural systems and sympathetic–para sympathetic systems activities and change in beta-1 adrenoceptors (33, 34). A different behaviour of left ventricular ejection fraction was suggested as a possible reason for the different behaviour of HRDP (35). It is also suggested that the deflection in heart rate may occur predominantly in subjects with thicker heart walls and does not seem to bear any relation to heart volume (36).

In this study, HRDP occurred in only 6 subjects (24%). However, it should be emphasized that correlation between HRDP and AT estimated with V-slope method occurred in only four subjects (16%) (Table). However, in 2 of the subjects, HRDP was not associated with the AT, and it occurred markedly above the AT. This overestimation of AT using HRDP was in consistent with some previously reported studies (27, 29). A deflection point in heart rate work rate relationship does not often occur, and, when it does, it does not coincide with AT, either in pre-training or post-training conditions (37). Despite the marked decrease in maximal exercise capacity and anaerobic threshold, the heart rate and work rate relationships did not affected during incremental exercise with breathing low level of O_2 (21).

It is suggested that exercise test protocol may have an important role on heart rate work rate deflection point during exercise (32, 38). During incremental exercise tests with various work rate increments have been shown no significant effects on heart rate work rate relationships (39).

In this study, while the heart rate increased linearly with increasing work rate, there was a clear break point at the transition from aerobic to anaerobic metabolism in work rate divided to heart rate ratio (Figure 1). The estimated AT from the V-slope break point significantly correlated to a deflection point in work rate divided to heart rate ratio during an incremental exercise test (Figure 2). It is well known that the V-slope method has been shown as the gold standard non-invasive method used to estimate AT. This method based only detecting the metabolic changes (18).

In conclusion, absent of break point in heart rate work rate relation and extremely low percent of association in AT estimation between HRDP and pulmonary gas exchange indices may reduce reliability of the Conconi test. Therefore, caution should be taken by investigators especially making important decision for patients and sports training. However, work rate to heart rate ratio could provide easy and reliable AT estimation, and importantly it may be incorporated to set exercise intensity parameters for patient's rehabilitation in clinical medicine.

Funding:

No funding.

Conflicts of interest:

There is no conflicts of interest.

Acknowledgements

Each author has participated sufficiently, intellectually or practically, in the work to take public responsibility for the content of the article, including the conception, design, and conduct of the experiment and for data interpretation.

References

1. Wasserman K, Hansen JE, Sue DY, et al. Principles of exercise testing and interpretation: Including pathophysiology and clinical applications. 5th Edition Philadelphia: Lippincott Williams & Wilkins, 2012.
2. Rossuello AE, Hawkins SA, Wiswell RA. Absolute lactate threshold predicts endurance performance in master athletes. Biol Sport 2009; 26: 105-112.
3. Ozcelik O, Ozkan Y, Algul S, Colak R. 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 Prefer Adherence 2015; 9: 999-1004.
4. Gitt AK, Wasserman K, Kilkowski C, et al. Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for high risk of early death. Circulation 2002; 106: 3079-3084.
5. Cordova C, Silva VC, Moraes CF, Simões HG, Nóbrega OT. Acute exercise performed close to the anaerobic threshold improves cognitive performance in elderly females. Braz J Med Biol Res 2009; 42: 458-464.
6. Sinclair RC, Danjoux GR, Goodridge V, Batterham AM. Determination of the anaerobic threshold in the pre-operative assessment clinic: Inter-observer measurement error. Anaesthesia 2009; 64: 1192-1195.
7. Yoshida T. Effect of exercise duration during incremental exercise on the determination of anaerobic threshold and the onset of blood lactate accumulation. Eur J Appl Physiol 1984; 53: 196-199.
8. Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. J Appl Physiol 1986; 60: 2020-2027.

9. Whipp BJ, Ward SA, Wasserman K. Respiratory markers of the anaerobic threshold. Adv Cardiol 1986; 35: 47-64.

10. Fawkner SG, Armstrong N, Childs DJ, Welsman JR. Reliability of the visually identified ventilatory threshold and V-slope in children. Pediatr Exerc Sci 2002; 14: 181-192.

11. Sue DY, Wasserman K, Moricca RB, Casaburi R. Metabolic acidosis during exercise in patients with chronic obstructive pulmonary disease. Use of the V-slope method for anaerobic threshold determination. Chest 1988; 94: 931-938.

12. Conconi F, Ferrari M, Ziglio PG, Droghetti P, Codeca L. Determination of the anaerobic threshold by a noninvasive field test in runners. J Appl Physiol 1982; 52: 869-873.

13. Bourgois J, Coorevits P, Danneels L, et al. Validity of the heart rate deflection point as a predictor of lactate threshold concepts during cycling. J Strength Cond Res 2004; 18: 498-503.

14. Carey DG, Raymond RL, Duoos BA. Intra- and inter-observer reliability in selection of the heart rate deflection point during incremental exercise: comparison to a computer-generated deflection point. J Sports Sci Med 2002; 1: 115-121.

15. Erdogan A, Cetin C, Karatosun H, Baydar ML. Non-invasive indices for the estimation of the anaerobic threshold of oarsmen. J Int Med Res 2010; 38: 901-915.

16. Grazzi G, Mazzoni G, Casoni I, et al. Identification of a VO_2 deflection point coinciding with the heart rate deflection point and ventilatory threshold in cycling. J Strength Cond Res 2008; 22: 1116-1123.

17. Hofmann P, Pokan R. Value of the application of the heart rate performance curve in sports. Int J Sports Physiol Perform 2010; 5: 437-447.

18. Mikulic P, Vucetic V, Sentija D. Strong relationship between heart rate deflection point and ventilatory threshold in trained rowers. J Strength Cond Res 2011; 25: 360-366.

19. Sentija D, Vucetic V, Markovic G. Validity of the modified Conconi running test. Int J Sports Med 2007; 28: 1006-1011.

20. Jones AM, Doust JH. The Conconi test is not valid for estimation of the lactate turnpoint in runners. J Sports Sci 1997; 15: 385-394.

21. Ozcelik O, Kelestimur H. Effects of acute hypoxia on the determination of anaerobic threshold using the heart rate-work rate relationships during incremental exercise tests. Physiol Res 2004; 53: 45-51.

22. Whipp BJ, Davis JA, Torres F, Wasserman K. A test to determine parameters of aerobic function during exercise. J Appl Physiol 1981; 50: 217-221.

23. Droghetti P. Determination of the anaerobic threshold on a rowing ergometer by the relationship between work output and heart rate. Scand J Sports Sci 1986; 8: 59-62.

24. Ballarin E, Borsetto C, Cellini M, et al. Adaptation of the “Conconi test” to children and adolescents. Int J Sports Med 1989; 10: 334-338.

25. Cellini M, Vitiello P, Nagliati A, et al. Noninvasive determination of the anaerobic threshold in swimming. Int J Sports Med 1986; 7: 347-351.

26. Droghetti P, Borsetto C, Casoni I, et al. Noninvasive determination of the anaerobic threshold in canoeing, cross-country skiing, cycling, roller, and iceskating, rowing, and walking. Eur J Appl Physiol 1985; 53: 299-303.

27. Gripp F, Lacerda AC, Goncalves R, Szmuchrowski L. Sustained, prolonged exercise at stable heart rate defined by the deflection point identification method. J Strength Cond Res 2009; 23: 632-637.

28. Wonisch M, Hofmann P, Schwaberger G, von Duvillard SP, Klein W. Validation of a field test for the non-invasive determination of badminton specific aerobic performance. Br J Sports Med 2003; 37: 115-118.

29. Nikolaizik WH, Knöpfli B, Leister E, et al. The anaerobic threshold in cystic fibrosis: Comparison of V-slope method, lactate turn points, and conconi test. Pediatr Pulmonol 1998; 25: 147-53.

30. Francis KT, McClatchey PR, Sumsion JR, Hansen DE. The relationship between anaerobic threshold and heart rate linearity during cycle ergometry. Eur J Appl Physiol Occup Physiol 1989; 59: 273-277.

31. Conconi F, Grazzi G, Casoni I, et al. The Conconi test: methodology after 12 years of application. Int J Sports Med 1996; 17: 509–519.

32. Bodner ME, Rhodes EC. A review of the concept of the heart rate deflection point. Sports Med 2000; 30: 31–46.

33. Pokan R, Hofmann P, Lehmann M, et al. Heart rate deflection related to lactate performance curve and plasma catecholamine response during incremental cycle ergometer exercise. Eur J Appl Physiol 1995; 70: 175-179.

34. Hofmann P, Wonisch M, Pokan R, et al. Beta1-adrenoceptor mediated origin of the heart rate performance curve deflection. Med Sci Sports Exerc 2005; 37: 1704-1709.

35. Pokan Hofmann P, von Duvillard SPR, et al. The heart rate performance curve and left ventricular function during exercise in patients after myocardial infarction. Med Sci Sports Exerc 1998; 30: 1475-1480.

36. Lucía A, Carvajal A, Boraita A, et al. Heart dimensions may influence the occurrence of the heart rate deflection point in highly trained cyclists. Br J Sports Med 1999; 33: 387-392.

37. Ozcelik O, Kelestimur H. Effects of aerobic exercise training on the heart rate-work rate relationship and estimation of anaerobic threshold in obese females. Turk J Med Sci 2006; 36: 165-170.

38. Vachon JA, Bassett DR, Clarke S. Validity of the heart rate deflection point as a predictor of lactate threshold during running. J Appl Physiol 1999; 87: 452-459.

39. Ozcelik O, Ayar H. Effects of exercise protocol on the estimation of anaerobic threshold based on heart rate-work rate relationships. Firat Medical Journal 2004; 9: 40-44.