TÜBİTAK

ORIGINAL ARTICLE

Turk J Med Sci
2006; 36 (3): 165-170

E-mail: medsci@tubitak.gov.tr

Effects of Aerobic Exercise Training on the Heart rate-Work rate Relationship and Estimation of Anaerobic Threshold in Obese Females

Oğuz ÖZÇELİK
Haluk KELEŞTİMUR

Department of Physiology,
Faculty of Medicine,
Fırat University,
Elazığ -TURKEY

Aim: The purpose of this study was to assess the effects of aerobic training on the relationship between the heart rate deflection point and anaerobic threshold (AT).

Patients and Methods: Seventeen untrained, obese subjects (body mass index: 39.5 ± 1.2 kg/m^2) completed 2 incremental ramp exercise tests (15 W/min) up to the point of exhaustion using an electromagnetically-braked cycle ergometer; once at the onset and once at the end of a 4-week period. All subjects participated in a regular anaerobic exercise training programme (45 min, 3 times per-week, for 4 weeks) combined with a hypocaloric diet. Heart rate was recorded with a polar monitor. AT was estimated using the ventilation-metabolism relationship, but was determined from capillary blood lactate samples.

Results: Of all the subjects, only 4 (23.5%) had a heart rate deflection during pre-training, while 3 (17.6%) did during post-training conditions. Additionally, the heart rate deflection point overestimated (20.6%) the AT: 90.0 ± 7.2 W vs. 75.7 ± 6.5 W (P = 0.01). After training, the heart rate-work rate relationship changed in 7 subjects.

Conclusion: These data indicated that a deflection point in heart rate does not often occur, and, when it does, it does not coincide with AT, either in pre-training or post-training conditions.

Key Words: Exercise test, heart rate deflection point, anaerobic threshold, obesity

Obez Bayanlarda Aerobik Egzersiz Antrenmanının Kalp Atım-İş Gücü İlişkisine ve Anaerobik Eşik Hesaplanması Üzerine Etkileri

Amaç: Bu çalışmanın amacı aerobik egzersizin kalp atım kırılma noktası ile hesaplanan anaerobik eşik üzerine etkilerini incelemek.

Hastalar ve Yöntem: On yedi antrenmansız obez denek (beden kitle indeksi 39.5 ± 1.2 kg/m^2) elektromanyetik bisiklet ergometre ile çalışmanın başında ve dördüncü haftasının sonunda olmak üzere iki tane artan yüke karşı yapılan egzersiz testini yoruluncaya kadar devam ettirdiler. Bütün denekler hipokalorik diyet tedavisi ile kombine olarak düzenli aerobik egzersiz antrenman programına alındılar (45 dk, 3 defa her hafta, 4 hafta süre ile). Kalp atımı polar monitör ile kaydedildi. Anaerobik eşik ventilasyon-metabolizma ilişkisi ile hesaplandı ve kapiller kan laktat örnekleri ile tespit edildi.

Bulgular: Bütün deneklerde kalp atım hızında kırılma noktası gözlenmedi, antrenman öncesi yalnızca dört denek (%23.5) ve antrenman sonrası üç denekte (%17.6) kalp atımında kırılma noktası gözlendi. İlave olarak, kalp atım kırılma noktası anaerobik eşikten sonra oldu: 90.0 ± 7.2 W ve 75.7±6.5 W (P=0.01). Antrenman sonrası, kalp atım hızı-iş gücü ilişkisi yedi denekte değişiklik gösterdi.

Sonuç: Bu sonuçlar bize kalp atımındaki kırılma noktasının çoğunlukla görülmediğini, görüldüğünde ise antrenmanlı ve antrenmansız durumda anaerobik eşik ile uyum göstermediğini ortaya koymaktadır.

Anahtar Sözcükler: Egzersiz testi, kalp atım kırılma noktası, anaerobik eşik, obezite

Received: October 19, 2004
Accepted: March 22, 2006

Correspondence

Oğuz ÖZÇELİK
Department of Physiology,
Faculty of Medicine
Fırat University, Elazığ-TURKEY

oozcelik@excite.com or

Introduction

In clinical and sport science, various tests have been introduced to determine the fitness level of individuals. During exercise, the point of transition from aerobic to anaerobic metabolism, which is known as anaerobic threshold (AT) (1), has been used as an index to assess aerobic fitness (1), to establish an appropriate level of exercise training intensity (2), and to preoperatively evaluate a patient undergoing major surgery (3).

The most accurate way to measure AT is based on the determination of the concentration of lactic acid, which requires frequent blood draws (4). Despite some controversy, many investigators demonstrated that AT can be accurately estimated, non-invasively, with methods based on ventilatory and pulmonary gas exchange indices in laboratory conditions (5). However, estimation of AT in subjects exercising outside of laboratory conditions is not easy and requires specialised equipment. Conconi et al. (6) introduced a simple, non-invasive method to estimate AT that is based upon the heart rate-work rate relationship. A deflection point in the heart rate-work rate relationship occurs when exercise intensity increases from aerobic to anaerobic intensity. It has been proposed that an observed deviation from linearity in the heart rate-work rate relationship during exercise coincided with AT (6). This test has achieved much popularity due to its relative simplicity and non-invasive nature.

There is a large body of literature concerning the heart rate deflection point and AT estimation. The physiological mechanisms of the deflection point in the heart rate-work rate relationship have yet to be completely understood. The results of the studies of the heart rate-work rate relationship are controversial; some studies showed a good relationship between the heart rate deflection point and AT (7-9), while others observed no significant relationship between the two (10,11).

To the best of our knowledge, however, a limited number of studies have been performed to assess the physiological effect of aerobic fitness on the heart rate-work rate relationship and AT estimation. The aim of this study was to assess the effects of aerobic training on the deflection point in the heart rate-work rate relationship and estimation of AT during incremental exercise tests.

Materials and Methods

Total of 17 obese women (body mass index > 30 kg/m^2), who sought therapy for obesity at the Endocrinology Department of our university hospital, voluntarily participated in the study. The subjects' mean (± SE) age, height, and body mass index (BMI) were 39.94 ± 2.7 years, 156.4 ± 1.2 cm, and 39.5 ± 1.2 kg/m^2, respectively. The nature of the study was explained to the subjects, and they were given an opportunity to ask questions about anything that was unclear. The protocol for this study was approved by the local Ethics Committee and informed, written consent was obtained from each patient at the beginning of the study. Before the study, each participant underwent a standard physical examination and laboratory tests to rule out abnormalities. This pre-participation medical screening included medical history, physical examination, hormonal analyses, and cardiovascular risk assessment. The patients with cardiac problems (ECG abnormality) and hormonal dysfunction of cortisol, thyroid, and insulin were excluded from the study. Concomitantly, all patients were encouraged to have a nutritionally balanced, mildly hypocaloric diet with an energy content of approximately 1200-1600 kcal/day. Body weight and height were measured to the nearest 0.1 kg and 0.5 cm, respectively. Body compositions were assessed using the leg-to-leg bioelectrical impedance method (Tanita Body Fat Analyser, model TBF 300).

The subjects were requested not to eat a heavy meal or smoke at least 2 h before the test and to also refrain from taking drugs or caffeine for a period of 12 h before the test. After becoming familiar with the testing equipment (a computer controlled, electromagnetically-braked cycle ergometer [Lode, Examiner]), each subject performed 2 incremental exercise tests until exhaustion (12); once at the onset and once at the end of the

4-week experiment period. The exercise test consisted of an initial period of 4 min of cycling at 20 W as a warm-up, followed by the work rate increasing by 15 W/min to the limit of the subject's tolerance (exhaustion). The subjects were required to maintain a constant pedalling frequency within the range of 60-80 rpm.

During the 4-week experiment, subjects performed regular, intensive exercise training 3 times per week; the training work rate was set to the AT. Each training session lasted approximately 45 min. Throughout the test, the heart rate was measured and recorded continuously at 5-s intervals with use of a Polar heart watch; these data were later downloaded to a computer for analysis. Heart rate reserve was estimated from the difference between heart rate at maximal exercise performance and at rest. The predicted heart rate was estimated (13).

AT was non-invasively estimated using the ventilation-metabolism relationship (14), and was actually determined from capillary blood samples. During exercise, a hand-held lactate analyser (Accusport, Roche Diagnostics, Mannheim, Germany) was used to determine blood lactate levels (15). In addition, heart rate, in response to the progressively increasing work rate exercise tests, was plotted to estimate AT.

Paired t-test was used to evaluate the statistical significance of the differences between pre-training and post-training responses. The significance level was $P < 0.05$.

Results

The 4-week aerobic training programme resulted in marked reductions (P = 0.0001) in body weight (from 96.6 ± 3.0 kg to 92.4 ± 3.0 kg; -4.3%) and fat mass (P = 0.0001) (from 44.1 ± 2.3 kg to 40.5 ± 2.1 kg; -8.1%) (Table). Maximal exercise capacity (Wmax) increased 33.3% (from 96 ± 4 W to 128 ± 3 W; P = 0.0001). The work rate at AT also increased 42.3% (from 59 ± 2 W to 84 ± 2 W; P = 0.0001) after aerobic training (Table).

Table. Values (mean ± SE) and percentages of change for maximal exercise performance (Wmax), work rate at the anaerobic threshold (AT), body weight (BW), fat mass (FM), and fat free mass (FFM) for pre-training and post-training.

	Pre-training	Post-training	% change	P
Wmax (W)	96 ± 4	128 ± 3	33.3	0.0001*
AT (W)	59 ± 2	84 ± 2	42.3	0.0001*
BW (kg)	96.6 ± 3.0	92.4 ± 3.0	-4.3	0.0001*
FM (kg)	44.1 ± 2.3	40.5 ± 2.1	-8.1	0.0001*
FFM (kg)	52.5 ± 0.9	52.0 ± 1.1	-0.9	0.4[NS]

*significant differences, NS: not significant

The heart rate at rest (83.3 ± 2.0 bpm vs. 77.4 ± 2.6 bpm; P = 0.02) and at 20 W cycling (129.1 ± 4.7 bpm vs. 110.0 ± 2.9 bpm; P = 0.0001) decreased significantly after training (Figure 1). However, there were no statistically significant differences between pre- and post-training values at AT (142.4 ± 4.5 bpm vs. 136.0 ± 2.7 bpm; P = 0.08) or at Wmax (159.7 ± 4.4 bpm vs. 161.1 ± 3.3 bpm; P = 0.6) (Figure 1). A linear heart rate was observed in 13 subjects (76.4%) until the point of exhaustion in pre-training and in 14 subjects (82.3%) in

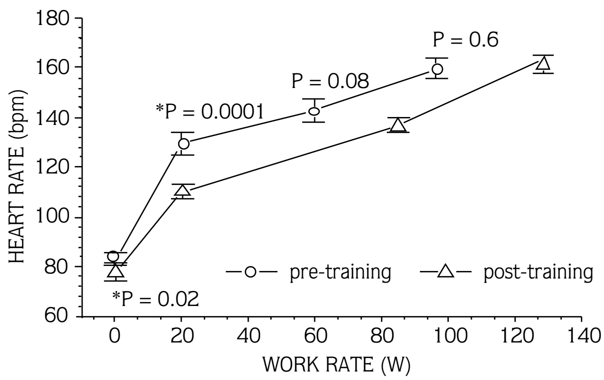

Figure 1. Heart rate (mean ± SE) response to the incremental exercise tests: at rest, during 20 W cycling, at the AT, and at maximal exercise performance, before (o) and after aerobic training (Δ). The vertical dashed line represents the predicted maximal heart rate.

post-training conditions. A downward deflection was observed in 2 subjects in pre-training and 3 subjects in post-training conditions (Figure 2). An upward deflection was observed in 2 subjects in pre-training condition (Figure 2).

The heart rate-work rate deflection point (4 in pre-training and 3 in post-training) did not match the AT in any of the subjects and occurred after the AT in both conditions (Figure 3). The work rate at the AT and at the deflection point were 75.7 ± 6.5 W and 90.0 ± 7.2 W, respectively; i.e. 20.6% above AT (P = 0.01). The heart rate at the deflection point was also higher (9.9%) compared to heart rate at the AT (154.7 ± 4.3 bpm vs. 141.1 ± 4.1 bpm; P = 0.02).

Discussion

During exercise, monitoring the heart rate-work rate relationship provides information about aerobic–anaerobic balance. Thus, it may be used as an index to evaluate physical fitness (6). The steady-state relationship between the heart rate and work rate is linear until the AT is exceeded. With further increases in work-rate, smaller changes may progressively occur in the heart rate-work rate relationship. Several studies highlighted that the transition from aerobic to anaerobic metabolism may correspond to the heart rate deflection point (7-9); however, there is controversy surrounding the heart rate deflection method as researchers do not always find a heart rate deflection during an incremental

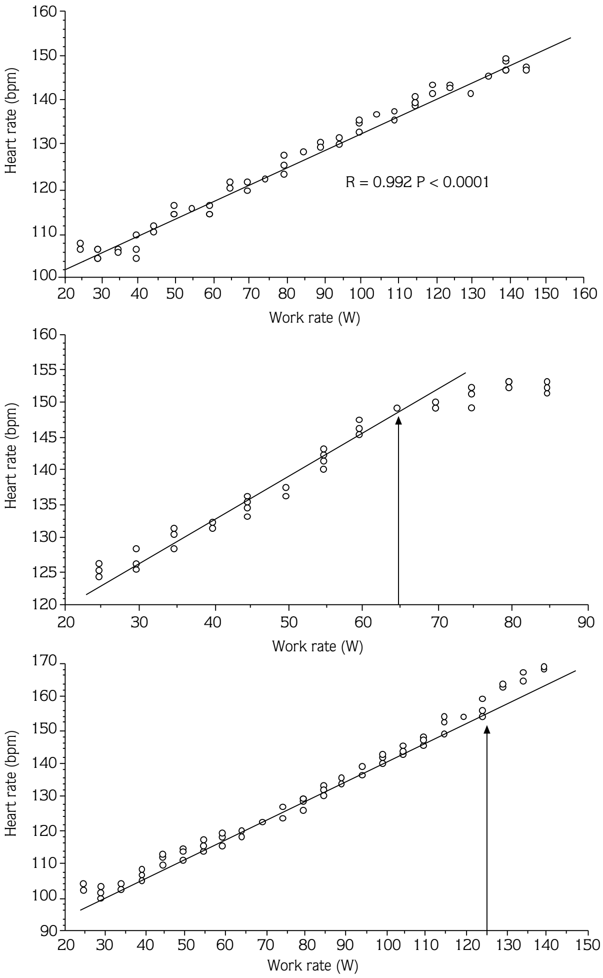

Figure 2. The heart rate-work rate relationship response to progressively increased work rate exercise: a) linear increase, b) downward deflection, c) upward deflection.

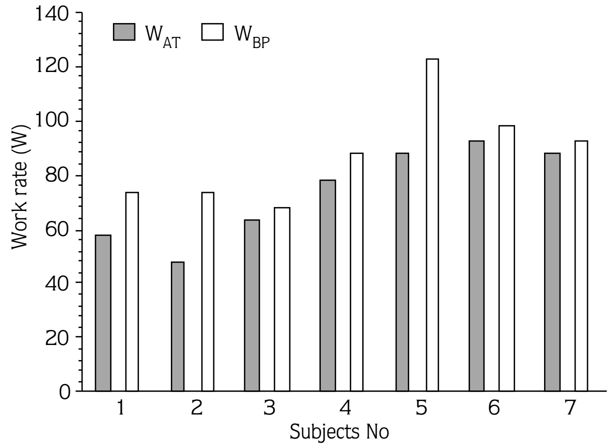

Figure 3. Work rates at the AT (WAT, grey column) and at the heart rate deflection point (WBP, white column) during incremental exercise tests.

exercise test (10,11). In our study group, 76.4% of the subjects in pre-training condition and 82.3% of the subjects in post-training condition showed no signs of a heart rate deflection. Another important finding of this study was that the heart rate deflection point occurred at much higher work rates than directly-measured AT. The break point in the heart rate-work rate relationship occurred at approximately 80% of Wmax. Furthermore, the deflection point in the heart rate-work rate relationship occurred at approximately 95% of maximum heart rate, both pre- and post-training (10). Short-term aerobic exercise training combined with a hypocaloric diet resulted in marked improvements in maximal exercise capacity (33%) and aerobic fitness as indicated by AT (39%) (16). Reduced sympathetic activity, which occurs in obese subjects (17), can be improved following aerobic exercise training (18).

Data observed in the present study did not support the proposition that heart rate can serve as a non-invasive marker of aerobic–anaerobic transition (10,11,19-21). The duration of exercise stages may be responsible for the loss of linearity between the heart rate-work rate relationship (21). It has also been reported that the heart rate break point is closely associated with the respiratory compensation point, defined as a systematic decrease in the fraction of expired CO_2 (19). Whether or not the relationship between the heart rate deflection point and the aerobic to anaerobic metabolic transition point is causal or simply coincidental remains to be established. The important question to be addressed here is why do some subjects show a heart rate deflection, while others have a linear heart rate response? The deflection point, or the linearity in the heart rate-work rate relationship, has yet to be fully elucidated. Increased lactate levels (22), exercise-induced hyperkalaemia (23), and left ventricular ejection fraction, which is an important parameter of myocardial function (24), have been implicated as contributing factors to heart rate deflection during exercise tests. During intense exercise, catecholamines have widespread effects that further push an organism toward its functional limits, including a break-point in the relationship between double product (the product of heart rate and systolic blood pressure) and work rate (25). During exercise, noradrenaline and adrenaline levels have been shown to be closely associated with the onset of a systematic increase in blood lactate concentration (26).

The physical condition of a particular subject may also be responsible for the deflection point in the heart rate-work rate relationship. In elite athletes, a downward deflection in heart rate response to exercise has been reported (27); however, in the present study, a downward deflection in heart rate response to exercise was observed in 2 subjects before training, but was not observed after aerobic training. In the present study, an increase was observed in the linear heart rate-work relationship during incremental exercise tests in 4 subjects in pre-training and 3 in post-training conditions.

The degree of heart rate deflection is highly dependent upon the type of protocol used in the study (28,29). It has been shown that obese subjects have lower cardiac performance during incremental exercise (30). Heart rate at rest and also at 20 W cycling lowered after training in the present study, reflecting improvement of diastolic filling and also systolic function; however, maximal heart rate did not increase after training. It is generally accepted that improvements in aerobic fitness are accompanied by a lowered resting heart rate, especially in endurance training.

Based on the results of the present study, the validity of the heart rate deflection point to assess AT is uncertain, as a strong linear relationship was found between heart rate and work rate, and the deflection point was not associated with AT, either in the pre- or post-training measurements. Therefore, investigators should be cautious when AT is determined by a single measure of heart rate-work rate response in clinical and sports medicine.

References

1. Wasserman K, Hansen JE, Sue DY et al. Principles of exercise testing and interpretation. (Ed. JM Harris) Lea & Febiger Publisher: Philadelphia, 1994; 52-72.
2. Casaburi R, Storer TW, Sullivan CS, et al. Evaluation of blood lactate elevation as an intensity criterion for exercise training. Med Sci Sports Exerc 1995; 27: 852-62.
3. Older P, Smith RER, Courtney P et al. Preoperative evaluation of cardiac failure and ischemia in elderly patients by cardiopulmonary exercise testing. Chest 1993; 104: 701-4.
4. Yoshida T, Nagata A, Muro M et al. The validity of anaerobic threshold determination by a Douglas bag method compared with arterial blood lactate concentration. Eur J Appl Physiol 1981; 46: 423-30.
5. Whipp BJ, Ward SA, Wasserman K. Respiratory markers of the anaerobic threshold. Adv Cardiol 1986; 35: 47-64.
6. Conconi F, Ferrari M, Ziglio PG et al. Determination of the anaerobic threshold by a noninvasive field test in runners. J Appl Physiol 1982; 52: 869-73.
7. Ballarin E, Sudhues U, Borsetto C et al. Reproducibility of the Conconi test: test repeatability and observer variations. Int J Sports Med 1996; 17: 520-4.
8. Carey D. Assessment of the accuracy of the Conconi test in determining gas analysis anaerobic threshold. J Strength Cond Res 2002; 16: 641-4.
9. Bodner ME, Rhodes EC, Martin AD et al. The relationship of the heart rate deflection point to the ventilatory threshold in trained cyclists. J Strength Cond Res 2002; 16: 573-80.
10. Jones AM, Doust JH. The Conconi test is not valid for estimation of the lactate turnpoint in runners. J Sports Sci 1997; 15: 385-94.
11. 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.
12. Whipp BJ, Davis JA, Torres F et al. A test to determine parameters of aerobic function during exercise. J Appl Physiol 1981; 50: 217-21.
13. Miller WC, Wallace JP, Eggert KE. Predicting max HR and the HR-VO2 relationship for exercise prescription in obesity. Med Sci Sports Exerc 1993; 25: 1077-81.
14. Hollmann W. Historical remarks on development of the aerobic-anaerobic threshold up to 1966. Int J Sports Med 1985; 6: 109-16.
15. Brinkert W, Rommes JH, Bakker J. Lactate measurements in critically ill patients with a hand-held analyser. Intensive Care Med 1999; 25: 966-9.
16. Kim HS, Tanaka K, Maeda K. Effects of exercise training at an intensity relative to lactate threshold in mildly obese women. Ann Physiol Anthropol 1991; 10: 229-36.
17. Peterson HR, Rothschild M, Weinberg CR et al. Body fat and the activity of the autonomic nervous system. N Engl J Med 1988; 318: 1077-83.
18. Amano M, Kanda T, Ue H et al. Exercise training and autonomic nervous system activity in obese individuals. Med Sci Sports Exerc 2001; 33: 1287-91.

19. Ribeiro JP, Fielding RA, Hughes F et al. Heart rate break point may coincide with the anaerobic and not the aerobic threshold. Int J Sports Med 1985; 6: 220-4.

20. Bourgois J, Vrijens J. The Conconi test: a controversial concept for the determination of the anaerobic threshold in young rowers. Int J Sports Med 1998; 19: 553-9.

21. Vachon JA, Bassett DR Jr, Clarke S. Validity of the heart rate deflection point as a predictor of lactate threshold during running. J Appl Physiol 1999; 87: 452-9.

22. Conconi F, Grazzi G, Casini I et al. The Conconi test- methodology after 12 years of application. Int J Sports Med 1996; 17: 509-19.

23. Lucia A, Hoyos J, Santalla A et al. Lactic acidosis, potassium, and the heart rate deflection point in professional road cyclists. Br J Sports 2002; 36: 113-7.

24. Hofmann P, Pokan R, Preidler K et al. Relationship between heart rate threshold, lactate turn point and myocardial function. Int J Sports Med 1994; 15: 232-7.

25. Riley M, Maehara K, Porszasz J et al Association between the anaerobic threshold and the break-point in the double product/work rate relationship. Eur J Appl Physiol 1997; 75: 14–21.

26. Mazzeo RS, Marshall P. Influence of plasma catecholamines on the lactate threshold during graded exercise. J Appl Physiol 1989; 67: 1319-22.

27. Lucia 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: 387-92.

28. Pokan R, Hofmann P, Von Duvillard SP et al. The heart rate turn point reliability and methodological aspects. Med Sci Sports Exerc 1999; 31: 903-7.

29. Stockhausen W, Grathwohl D, Burklin C et al. Stage duration and increase of work load in incremental testing on a cycle ergometer. Eur J Appl Physiol Occup Physiol 1997; 76: 295-301.

30. Salvadori A, Fanari P, Fontana M et al. Oxygen uptake and cardiac performance in obese and normal subjects during exercise. Respiration 1999; 66: 25-33.