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Original Article / Özgün Araştırma

Evaluation of Heart Rate, Work Rate and O_2 Uptake Relationships During Constant Load Exercise Test Work Load at the Anaerobic Threshold in Healthy Male

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Abstract

Objectives: During an incremental exercise test, increased metabolic demands of exercising muscle should be compensated with increased O_2 uptake and heart rate until to their maximal levels. Anaerobic threshold (AT) describes the point of metabolic transition from aerobic to anaerobic metabolism and reflect moderate exercise intensity. The aim of this study was to evaluate O_2 uptake to heart beat ratio (O_2 pulse) and heat rate to work rate ratio (HR/WR) in response to constant load exercise at work load corresponded to AT.

Method: Twelve healthy young male subjects initially performed an incremental exercise test (15 W/min) until exhaustion. Then, each subject performed a 30 min of constant load exercise test that work load at their AT on separate days. Pulmonary gas exchange parameters were measured breath-by breath using a metabolic gas analyser. Cardiac parameters were followed continuously beat-by beat using a 12 lead ECG. AT estimated non-invasively using V-slope method.

Results: The heart rate for each watt of work production (HR/WR) was ranged between 0.97 beat/min/W to 1.76 beat/min/W and averaged 1.25±0.2 beat/min/W. The O_2 pulse was ranged between 10.56 mL/min/beat to 16.15 mL/min/beat and averaged 13.38±1.5 mL/min/beat at the end of the test. A negative statistically significant correlation ($R = -0.90316$, $p<0.0001$) between HR/WR and O_2 pulse values were observed. In addition, a negative statistically significant correlation ($R = -0.67621$, $p<0.01$) were observed between O_2 uptake for each kg of body weight reflecting fitness status of subjects and O_2 pulse values.

Conclusion: Increased heartbeat for each watt of work production is conversely related with the fitness status of subjects. Measurements of O_2 pulse and HR/WR during aerobic exercise can provide valuable information with regarding subject's fitness status. Investigators should be considering moderate intensity aerobic exercise instead of using incremental exercise that contains aerobic and anaerobic work production.

Keywords: Exercise, Anaerobic threshold, O_2 pulse, fitness status, heart rate to work rate ratio

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Sağlıklı Erkek Bireylerde Sabit Yük Egzersiz Testi Sırasında Kalp Hızı, İş Oranı ve O_2 Alımı İlişkisinin Değerlendirilmesi

Öz

Giriş: Incremental egzersiz testi sırasında kas egzersizinde artan metabolik ihtiyaçlar, maksimum düzeylere kadar artan O_2 alımı ve kalp atımı ile kompanse edilmelidir. Anaerobik eşik (AE), aerobik metabolizmadan anaerobik metabolizmaya geçişi ve orta yoğunluktaki egzersizi tanımlar. Bu çalışmanın amacı, AE'e karşılık gelen sabit yük egzersiz karşısında O_2 alım-kalp atım oranı (O_2 pulse) ve iş gücü oranlarını değerlendirmektir (HR/WR).

Yöntemler: On iki sağlıklı, genç, erkek bireye gidebilecekleri son noktaya kadar (15W/min) incremental egzersiz testi uygulandı. Daha sonra her bireye ayrı günlerde AE'de 30 dakikalık sabit yük egzersiz testi uygulandı. Pulmoner gaz değişim parametreleri, metabolik gaz analizörü kullanılarak nefesten nefese ölçüldü ve kardiyak parametreler 12'li EKG cihazı ile ölçüldü. AE, non-invasiv V-slope metodu ile değerlendirildi.

Bulgular: Her bir watt iş üretimi (HR/WR) için kalp atım hızı 0.97 atım/dak/W ile 1.76 atım/dak/W ve ortalama 0.2 atım/dak/W 1.25±0.2 atım/dak/W arasındaydı. O_2 pulse 10.56 mL/dak/atım ile 16.15 mL/dak/atım arasındaydı ve testin sonunda 13.38±1.5 mL/dak/atım olarak bulundu. HR/WR and O_2 pulse değerleri arasında istatiksel olarak anlamlı bir korelasyon ($R = - 0.90316$, $p<0.0001$) bulundu. Ek olarak bireylerin fitness durumunu yansıtan vücut ağırlığının her kg'ı için O_2 alımı ve O_2 pulse değerleri arasında istatistiksel olarak anlamlı bir korelasyon ($R = - 0.67621$, $p<0.01$) bulundu.

Sonuç: Her W iş üretimi için artan kalp atışı, bireylerin kondisyon durumu ile ters orantılıdır. Aerobik egzersiz sırasında O_2 pulse ve HR/WR ölçümleri, bireyin fitness durumu hakkında değerli bilgiler sağlayabilir. Araştırmacılar, aerobik ve anaerobik iş üretimi içeren incremental egzersiz testi kullanmak yerine orta yoğunluklu aerobik egzersiz testi düşünmelidirler.

Anahtar kelimeler: Egzersiz, anaerobik eşik, O_2 pulse, fitness durumu, kalp atış hızı/iş oranı.

INTRODUCTION

Cardio Pulmonary Exercise Testing (CPET) is the determination of a person's functional status of the metabolic and cardiorespiratory systems during muscular exercise by measuring the metabolic gas exchange and some other parameters[1]. An important aspect of CPET is the determination (or estimation) of the anaerobic threshold (AT) that indicates the transition point of aerobic metabolism to anaerobic metabolism occurs during an incremental exercise[2].

AT could be determined from the systematic increase in blood lactate levels or estimated from ventilatory and pulmonary gas exchange parameters[3-5]. AT has been widely used for various purposes in clinical medicine and sport sciences including establishing optimal training work[6], assessment of prognosis of patients[7] evaluation of fitness status[8] and post-operative progress in patients' condition[9].

Measurements of cardiac and O_2 uptake parameters under the condition of various type of exercise stress provides valuable information about the subjects' physical fitness status. During exercise, the quotient of O_2 uptake (VO_2) and heart rate (HR) is called as the O_2 pulse (VO_2/HR, mL O_2 per beat) and has been used to estimate cardiac pump functions[10]. In clinical medicine, the exercise peak O_2 pulse values can be used to evaluate cardiac output and detect existence of myocardial function impairments[11-13].

The workload corresponded to AT reflects moderate exercise intensity dominated by aerobic metabolic system activity. Thus, work rate O_2 uptake and heart rate response to the constant load aerobic exercise may also provide important information with regarding O_2 supply and transportation and utilisation systems. The aim of this study was to evaluate O_2 uptake to heart beat ratio and heat beat to work rate ratio in response to the constant load exercise at work load corresponded do AT in healthy male subjects.

METHODS

Twelve young sedentary male subjects initially performed an incremental exercise test. Signed writing informed contents which were approved by the local ethic committee (06.05.2014/09.01) were obtained from ach subjects before participating to this study. The subjects should be in normal body mass index (18.5 kg/m2 - 25 kg/m2), age between 18-25. The subjects should be free in any medical problems. They have no smoking or drinking alcohol or taking any medication. The subject's physical characteristics are: age 21±2 year, weight 75.9 ±5 kg and height 184±8 cm. All exercise tests were performed in a climatically controlled laboratory.

The incremental exercise test protocol started with 20 W cycling at 20 W/min as a warm-up period to unsure that subjects were in steady-state condition[14] using a cycle ergometer (VIA sprint TM150/200P). Then work load increased with a work rate controlled by 15 W/min until the subject's limit of tolerance as an incremental period. Then, the workload reduced 20 W/min to cycle for a couple of minutes as a recovery period[15]. Then, on a separate day (after 3 day), each subjects performed a constant load exercise test for a 30 min at work rate corresponded to their AT that estimated after incremental exercise test.

The subject's anaerobic threshold was estimated non-invasively using V-slope method[4] and also other conventional ventilatory and pulmonary gas exchange parameters[16,17].

During exercise, a twelve lead ECG was placed to each subject and cardiac parameters (including ST segment, T wave, QT and heart beat) were followed continuously through the test. The subjects ventilatory and pulmonary gas exchange parameters were evaluated breath-by-breath using metabolic gas analyser system (Master Screen CPX, Germany). During exercise, minute ventilation (VE), O_2 uptake (VO_2), CO_2 output (VCO_2) and heart rate (HR) were measured. O_2 pulse estimated using VO_2 to each heart beat (ml O_2 per beat). The data are expressed as means (± standard deviation [SD]). A linear regression analyses was used to analyse statistical significance between parameter used to identify fitness status, including heart rate, work rate and O_2 uptake parameters. $P<0.05$ was accepted as a statistically significance.

RESULTS

During incremental exercise, the subjects maximal exercise capacity (Wmax), work rate at the AT (WAT) and O_2 uptake at maximal exercise (VO_2max) were found to be 213±29 W, 129±20 W and 2.84±0.3 L/min, respectively. AT occurred at approximately 60% of maximal exercise performance. The subjects O_2 uptake for each kg of body weight at maximal exercise was ranged between 30.6 ml/min/kg to 46.2 ml/min/kg and averaged 37.4±4 ml/min/kg. Metabolic equivalent (MET) value was ranged between 8.7 to 13.2 and averaged 10.7±1.2.

The subjects heart rate was 91±8 beat/min at warm-up and increased to 158±14 beat/min at the end of the test. This was coincided with 79% of predicted maximal heart rate (199±2 beat/min). The heart rate for each watt of work production was ranged between 0.97 beat/min/W to 1.76 beat/min/W and averaged 1.25±0.2 beat/min/W. In addition, during constant load exercise test, heartbeat to work rate ratio (ΔHR/ΔWR) was ranged between 0.44 beat/min/W to 0.95 beat/min/W and averaged 0.62374 beat/min/W.

There was a negative significant correlation between increased O_2 uptake for each kg of body weight and change of heart rate to work rate ratio (Figure 1).

During constant load exercise test, O_2 uptake at the warm-up period was found to be 0.69±0.07 L/min and it increased to 2.11±0.25 L/min at the end of the exercise. O_2 uptake at the end of

constant load exercise was ranged between 21.0 mL/min/kg to 36.2 mL/min/kg and averaged 27.8±3.9 mL/min/kg. The O_2 pulse was found to be 7.65±0.8 mL/min/beat at the warm-up period and 13.38±1.5 mL/min/beat at the end of the test (ranged between 10.56 mL/min/beat to 16.15 mL/min/beat). MET value was ranged 6.0 and 10.3 and averaged 7.9±1.1. There was a negative significant correlation between heart rate to work rate ratio and O_2 pulse values (Figure 2).

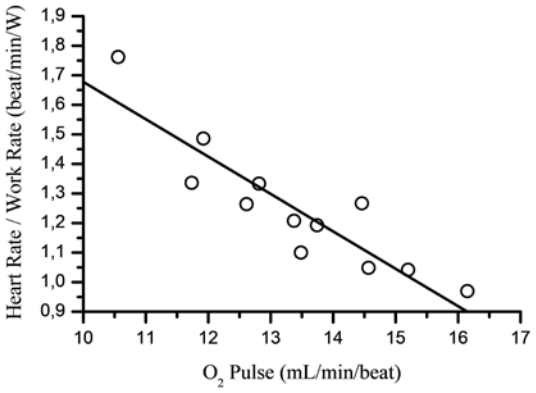

Figure 1: The correlation analysis between O_2 uptake for each kilogram of body weight at maximal exercise performance (VO_2max/BW) and heartbeat to work rate ratio (ΔHR/ΔWR) during constant load aerobic exercise. (R = -0.67621 n=12p<0.01)

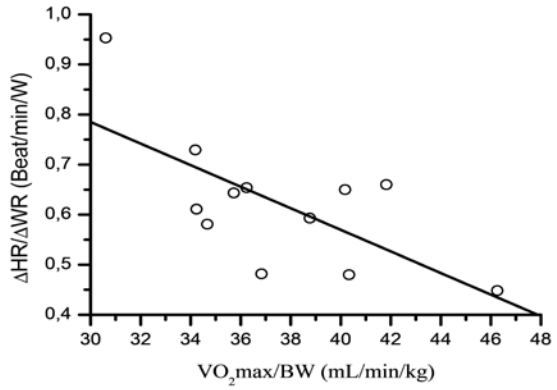

Figure 2: The correlation analysis between O_2uptake for each heart beat (O_2 Pulse) and heartbeat to work rate ratio during constant load aerobic exercise. (R = -0.90316 p<0.0001.

DISCUSSION

The results of this study showed that moderate intensity constant load exercise based on aerobic metabolism resulted significant variation in O_2 pulse levels among the subjects. A steady state condition of VE, VO_2, VCO_2 and heartbeat is the general observation of aerobic constant load exercise test[18,19]. The workload corresponded to AT based on solely aerobic metabolism may not cause increase in blood lactate levels and reflects moderate exercise intensity[10,20]. In the present study, AT occurred at 60% of maximal exercise capacity, which is accepted as normal ranges[1].

We have found that the ration of heart rate to work rate was closely related with the fitness capacity of the subjects[21]. As shown in Figure 1, subjects' fitness status as determined from VO_2max/BW was significantly correlated with the heart rate for each work production capacity. It has been shown that increased ΔHR/ΔWR is closely related with the cardiac function capacity[22]. There is also negative correlation between increased heart rate to work rate ratio and decrease in O_2 pulse values at the AT (Figure 2). Exercise O_2 pulse is an effective criterion to evaluate fitness status levels of the subjects. The peak O_2 pulse has been used as an indicator of diseases severity for patients with respiratory[23] and cardiac system dysfunctions[24].

O_2 pulse is simply product of arterial and venous blood O_2 differences and stroke volume. During exercise, increase in stroke volume in response to the increased metabolic demands of exercising muscle is important factor for trained and untrained subjects[25]. The variation of O_2 pulse levels attenuated at the end of moderate intensity exercise may reflects differentiation in peripheral O_2 extraction and or cardiac performance levels among the subjects. The number of mitochondria is important factor on peripheral O_2 extraction[26]. Studies shown that trained athletes have

greater capacity to peripheral O_2extraction capacity during exercise[27]. Peak O_2 pulse provides status of left ventricular function and its prognosis[28,29].

Exercise intensity corresponded to AT is the moderate intensity at which stroke volume nearly reaches plateau[30]. Increased HR/WR may result decrease in O_2 pulse and O_2 uptake for each kg of body weight. The constant load aerobic exercise could provide valuable information with regarding fitness status of the cardiac respiratory and metabolic system function of the subjects[31].

CONCLUSION

Consequently, moderate intensity aerobic exercise may allow the determination of key prognostic variables and can be distinguishing pathophysiology not apparent at rest in subjects could not be perform incremental maximal exercise performance.

Ethics Committee Approval: The local research and ethics committee approved the study protocol, and the study was conducted following the ethical principles described by the Declaration of Helsinki.

Declaration of Conflicting Interests: The authors declare that they have no conflict of interest.

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