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THE MEASUREMENT OF MAXIMAL O2 PULSE BY THE GAS ANALYZER (DIRECT METHOD) IN ACTIVE MALE STUDENTS: A COMPARISON OF THREE PROTOCOLS

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ABSTRACT

Objective: The purpose of this study was to investigate the measurement of maximal oxygen pulse (maximal O2 pulse) by the gas analyzer (direct method) with a comparison of three protocols in active male students. ***Methodology:*** This investigation was in the form of a semi-experimental. 23 active male athletes with having average age (22.2±2.01 yr), which the purposefully were selected, participated in this study. Maximal O2 pulse values from Bruce treadmill exercise, bike Strand and Queen Stair's tests using respiratory gas analyzers were measured. To select an appropriate exercise test then, peak O2 pulse values obtained from two standard Bruce protocol were compared with the reference protocol. In the statistical analysis, One-way ANOVA at a significance level of 5% was used to compare protocols. ***Results:*** The results of this study showed that Bruce exercise test provides more accurate measurement of maximal O2 pulse compared to the Queen's step and Strand tests (by gas analyzer) that showed significant difference ($P<0.05$), while Queen's step test showed no significant difference compared to Strand test ($P>0.05$). ***Conclusion:*** The results in this study suggested that the measurement of maximal O2 pulse (as a cardiovascular index) by the gas analyzer (direct method) in Strand exercise test have higher values than that of Queen's step test.

Keywords: Maximal O2 pulse, functional cardiovascular tests, active male.

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INTRODUCTION

One of the controversial issues in the field of Sport Sciences and Physiology is the efficiency and capacity of the cardiovascular system. Identify of cardiovascular function and markers indicator of the effectiveness of this system make the appropriate fields of study to professionals and researchers. In recent years, variables such as heart rate, cardiac output, blood pressure and volume in the cardiovascular system function were presented at resting and exercising conditions and have also been used in research and clinical trials[1] . In the annual meeting of the cardiac rehabilitation centers of the United States, was noted that the many cardiovascular diseases in active people can be detected by Oxygen pulse (O2 pulse) researches. O2 pulse is the amount of oxygen comes out with each beat of the cardiovascular system and it is one of the measurements of cardiovascular system function [2] . In general, by the transition from the resting phase to the early stages of exercise, O2 pulse rate increases and this increase is slower in the later stages, which it's increasing is proportional to body oxygen needed[3] .Those who have less oxygen pulse in the first few minutes of the test than others, have lower cardiovascular performance than others in resting state [2-4].

Direct measurement of the O2 pulse at resting and exercising mood can obtain a precise estimate of the index of cardiorespiratory fitness[5]. The maximal O2 pulse, the volume of oxygen carried by the blood and extracted by peripheral tissues in each heart beat is maximum during exercise and achieved by the ratio of the maximum heart rate to maximal oxygen consumption (VO_{2max}) and expressed in millimeter oxygen per beat and it is the major indices to estimate stroke volume and arterial venous oxygen difference (a-vO2 diff) and VO_{2max} at cardiodynamic adaptations. O2 pulse as an index of cardiac function can be used extensively. Fellmann et al (2003) reported maximal O2 pulse as an appropriate index for estimating exercise intensity and energy cost[6].

Lavie et al (2004) have mentioned on their research report that O2 pulse is as a marker of prognosis in coronary disease and heart failure and also as an estimator of cardiovascular function. Moreover, they believe that the maximal O2 pulse as a predictor of maximal oxygen uptake in the clinical setting is preferred in most cases. The high O2 pulse compared to healthy athletes and healthy inactive individuals, non-athletes compared to of immobile patients, the has emphasis on performance indicators[7]. The O2 pulse as a marker of prognosis has been proven in several studies[1]. Improved peak O2 pulse is as improved heart function and may impact the improvement of athletic performance[8]. Fellmann et al (2003) studies show a significant increase in oxygen pulse followed by an interval training courses[1-9]. The rapid increase of O2 pulse in the early stages of exercise depends on changes in stroke volume and increased arterial oxygen difference[3].

In order to measure peak oxygen pulse the direct method of respiratory gas analysis, that is the most accurate method, was used.It is important to choose the correct exercise protocol as the best measurement of maximal oxygen pulse to characterize more precisely the cardiovascular performance of the athlete. Therefore, the aim of this study was to determine the accurate measurement of peak exercise oxygen pulse by three protocols, Bruce treadmill, bike Strand and Queen step in order to increase maximize cardiovascular efficiency of athletes, using the direct method of respiratory gases analysis (gas analyzer), respectively.

Materials and Methods

Method of semi-experimental was used in this study. The research includes active male university students with an age range of 19 to 23 years the University of Mohaghegh Ardabil. Athletes with a mean age of 21.2 ± 2.01 years and peak oxygen consumption 52.00±3.39

ml/kg/min were purposefully selected and the subjects were selected, details (oral and written) about the research process and how to do it, in terms of research and testing were presented. In the next stage the subjects a questionnaire containing valid information including health status and level of physical activity were given to Participants[1-2]. Inclusion criteria for this study due to its special features are: Age category 19 to 23 years, no previous history of heart disease - cardiovascular or respiratory, lack of participation in strenuous activity for 48 hours before testing, not using alcohol and smoking, and not using of illegal drugs and/or drug substances; A constant diet during the exercise protocol, cardiorespiratory fitness moderate to high (≤ 40% VO_{2max}).

Physical characteristics and body composition

First, the personal information of the participants was recorded. Then, anthropometric variables and body composition, age, height, weight, BMI, percent body fat (two point method Lohman), fat and free fat mass were measured[10].(Table 1). Wall height gauge with one--millimeter accuracy and a digital scale with one hundred grams accuracy, made by Seca Germany Company, and were used to measure the height and weight. Subcutaneous fat areas of the body including triceps and leg are estimated by using dynamic Harpenden caliper to achieve body fat percentage too. Finally ,formula 1 and 2 were used to calculate the fat-free mass and muscle mass.

Formula 1: fat-free weight (FFW) = body weight – fat percentage

Formula 2: fat weight = fat percentage – body weight

Table 1. Individual characteristic in participants.

Variable	Mean±SD (N=23)	Range (minimal - maximal)
Age (years)	21.2±2.01	(19-23)
Weight (kg)	66.96±5.42	(55-75)
Height (cm)	175.52±4.6	(165-185)
Fat percentage (%)	9.3±3.43	(6.5-14.5)
Resting heart rate (beat . min^{-1})	67.9±4.32	(61-74)
VO2max (ml/kg/min)	52.00±3.99	(44-52)
Maximal heart rate (beat . min^{-1})	191.34.88	(185-200)

Maximum heart rate is measured by the gas analyzer with exercise tests
Bruce treadmill test

After calibrating gas analyzer set, sample information, such as name, age, height, weight, and gender were recorded. Calibrating gas analyzer before and after each exercise test was performed in accordance with its instructions. Incremental exercise protocol on a treadmill to determine peak O2 pulse was performed by participants. Bruce test performed on the treadmill, sport model (RTE) 6150 made in Germany, included a total of 7 stages. Participants in the first five minutes did stretching exercises (especially the large muscles of the lower body) to avoid risks and potential damage. Then, the participants were asked to walk on a treadmill with a slope of zero and 1.5 km as a warm-up walk. The first stage of the test began with a slope of 10% and 2.7 miles per hour. The second stage, the speed and incline increased. As the third and the fourth stage started walking fast and if able, they continue to run. Each stage of Bruce test lasted three minutes and slope and the speed were increased in every step until the participant reached exhaustion. In order to take maximize the ability of the participants there to stethoscope polar device, model M-31 made in Finland, had closed to their chest to determine their heart rate. In this test, when participants was going to be extreme fatigue during exercising and unable to continue exercise, activities were halted. Participants usually arrived exhaustion in the fourth or fifth stages. Upon stopping, the information of participants such as exercise time, heart rate, maximal oxygen uptake (VO_{2max}) and maximal oxygen pulse were recorded by the monitoring system.

Astrand ergometer test

After calibrating gas analyzer and recording personal information, participants used the ergometer bicycle (maximal exercise protocol) to do Astrand test. The initial workload in this test was 600 kg m-test for men (100 kW). Resistance 2 kg (2 kg × 6 m × 50 m per minute rpm = 600 kg) and 2 to 3 minutes per exercise, workload amounts to 300 kg m (equivalent to 50 watts) were added. This test would continue until the participant was exhausted or unable to press the pedal to maintain 50 rpm.

Queen's step test

After calibrating gas analyzer and recording personal information, participant started the Queen's Step test (submaximal exercise) with a command rate of 24 steps per minute for 3 minutes (96 steps per minute). Relevant information, using descriptive and inferential statistical methods, all analyzes were carried out using SPSS 16.00 for Windows. Statistical significance was set at $P < 0.05$. Normality of the distribution was assessed using the Kolmogorov-Smirnov test. One-way ANOVA test was used for comparison of maximal O2 pulse of 3 exercise protocols, and if the differences turned out to be significant, Tukey test (Tukey post hoc) was also used.

Results

The results of this study showed that Bruce exercise test provides more accurate measurement of maximal O2 pulse compared to the Queen's step and Strand tests (by the gas analyzer) that showed significant difference (P<0.05) (Tables 2), while Queen's step test showed no significant difference compared to Strand test (P>0.05) (Table 3).

Table 2. The comparison of maximal O2 pulse with Bruce treadmill, Astrand ergometer, and Queen's step exercise protocols by the gas analyzer (direct method) in (active male students.

Exercise protocol Variable	**Bruce treadmill test**	**Astrand ergometer test**	**Queen's step test**	**Levens test**	**P**	**F**	**P**
Maximal O2 pulse	18.04±2.21	15.18±2.29	14.46±2.54	0.211	0.810	14.88	0.001*

* *P*<0.05, significantly different from baseline values.

Table 3. Tukey test results for O2 pulse relates to three exercise protocols in a single group this study.

	Exercise protocol		Mean difference	Standard error	P
Tukey post hoc	Bruce treadmill test	Astrand ergometer test	2.86	0.69	0.001*
		Queen's step test	3.58	0.69	0.001*
	Astrand ergometer test	Bruce treadmill test	-2.86	0.69	0.001*
		Queen's step test	0.72	0.69	0.55
	Queen's step test	Bruce treadmill test	-3.58	0.69	0.001*

	Astrand test	ergometer	-0.72	0.69	0.55

* $P<0.05$, significantly different from baseline values.

Discussion and conclusions

The results showed that the maximal O2 pulse values - maximal oxygen consumption (VO2max)/maximal heart rate (HRmax) ratio, which is used in the assessment of cardiovascular function – in the Bruce test was significantly greater than the Astrand and Queen's step exercise protocols ($p<0.05$), thus more accurate and higher values compared to the other proposed protocols. In other words, maximal O2 pulse in the Bruce protocol (maximal test) showed the highest efficacy of cardiovascular in the subjects; that is Bruce test cardiovascular evaluation showed better than the other two protocols. These findings are consistent with the results of Grund et al (2000) and Buchfuhrer et al (1983), While the findings Wiswell et al (1979) that the O2 pulse during submaximal exercise is a good indicator of cardiovascular fitness[13] and Müller et al (2002) that the normal and overweight subjects with no significant difference in the amount of oxygen pulse [14], is inconsistent.

Grund and colleagues (2000) examined the relationship between physical activity, physical fitness and exercise parameters in 88 children's (normal weight, overweight and obese children's). In this study for the evaluation of physical fitness of subjects, consider that the values of oxygen pulse during incremental exercise protocol on the bicycle ergometer was determined. The results showed that oxygen pulse during heavy exercise in obese children is higher than in normal weight and overweight children. When oxygen pulse values were expressed relative to body weight and body fat in subjects, Children with normal weight had higher oxygen pulse values than the overweight and obese groups. In addition, this study showed that boys than girls have higher levels of oxygen pulse [11]. Buchfuhrer and colleagues (1983) investigated optimizing the exercise protocol for cardiopulmonary assessment; oxygen pulse in 12 healthy men using two Incremental exercise tests to exhaustion on treadmill and ergometer cycle. The results indicate that the oxygen pulse from performing a treadmill protocol was significantly higher than the ergometer bicycle[12]. It is likely that the increase in maximal O2 pulse values from Bruce test on a treadmill through the following mechanisms:

1. Age, height, weight, body size, lean body mass, blood volume, hemoglobin levels, fitness, and activity level are factors that can affect the O2 pulse [7];
2. More or less active muscles involved in the exercise. In other words, because the upper limb muscles were less involved in the Strand test (ergometer cycle) and muscle involved also in the Queen's step test is less than the Bruce test. Therefore, in the Strand test is used less oxygen and oxygen pulse values can be influenced [1].
3. Wasserman and colleagues also reported that low stroke volume is the main reason for low values of O2 pulse in subjects. They confirmed that if the stroke volume decreases, the arteriovenous oxygen differences and O2 pulse will reach their peak values in relatively intense exercise [1-2]. Thus, it is possible Strand ergometer bicycle test and Quinn steps in this research have been unable to raise the amount needed to stroke volume in subjects.

In general, the transition from the resting phase to the early stages of exercise, oxygen pulse increased rapidly in later stages of activity is slower, so increasing the oxygen pulse is proportional to the increase of oxygen the body needs [1]. Long-term studies show that the oxygen pulse and arterial venous oxygen difference during submaximal exercise followed by endurance training significantly increased [15]. However, cross-sectional studies are not consistent with these results, and do not show significant differences in any of these variables trained and untrained men.

The results showed that the maximal O2 pulse, which is an indicator of the efficiency of the cardiovascular system, with Bruce treadmill exercise test showed better values. In other words, the bicycle Astrand and Queen's Step tests useful information about the performance of the cardiovascular system in young men who did not exercise. Furthermore, this researches not only tests the direct measurement of maximal oxygen pulse was introduced, but also indicated this factor as an important indicator of cardiovascular prediction. Therefore, direct measurement of maximal O2 pulse with Bruce test will show better results of cardiovascular function. However, to prove this by direct measurements (measured with a gas analyzer) the maximal O2 pulse is needed to test various and different intensity exercises. Therefore, the researchers recommended that the maximal O2 pulse measurement by gas analyzer method in both men and women should be tested to be chosen an appropriate exercise for this novel cardiovascular index.

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